ESTIMATES OF COUNTY-LEVEL NITROGEN AND PHOSPHORUS DATA FOR USE IN MODELING POLLUTANT REDUCTION

DOCUMENTATION FOR SCENARIO BUILDER VERSION 2.2

COMPLETED FOR THE U.S. EPA

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TABLE OF CONTENTS

FIGURES

TABLES

1 OVERVIEW OF THE NUTRIENT AND SEDIMENT SCENARIO BUILDER

1.1 Purpose of the Scenario Builder

The Chesapeake Bay Program is facilitating increased nutrient and sediment control strategies by creating a framework and toolkit for adaptive management. The Chesapeake Bay Program recognizes that integrating regional water quality needs into local land use decisions is critical to restoring the Bay. The Chesapeake Bay Program has worked for 25 years to track progress toward abating nitrogen, phosphorus, and sediment pollution in the Bay. With the onset of a basin-wide TMDL and amidst criticism of overestimating progress in achieving nutrient and sediment load reductions, the Chesapeake Bay Program, through a grant to the University of Maryland, is developing a free and on-line decision-support tool known as the Nutrient and Sediment Scenario Builder. This tool is designed to assist planners in meeting cap-loads associated with the TMDL. Since the Bay Program staff will also use this tool, the methods used for tracking progress will become more transparent.

The tool is designed for rapid scenario development so users may understand the impacts of best management practices and land use change, as well as develop more effective nitrogen and phosphorus management strategies. In essence, Scenario Builder allows local governments and watershed organizations to translate land use decisions such as zoning, permit approvals and BMP implementation into changes in pounds of nitrogen, phosphorus and sediment originating from a particular county or watershed. The underlying model to the Nutrient and Sediment Scenario Builder is process-based. The sources of nutrients include farm animals, chemical fertilizer, biosolids, septic and sewer systems(although sewer is not currently in this model). Users can estimate the impact of land use changes on nutrient and sediment loads by comparing scenarios. The implication of where and which best management practices are applied may also be determined. This information can help users target limited resources to the locations where they will have the most impact. Exploring these scenarios, coupled with monitoring and explanatory information, provides a powerful adaptive management tool to decrease nutrient and sediment loads to the Chesapeake Bay.

The Scenario Builder is also used to provide the inputs to the Chesapeake Bay Program's Watershed Model – Hydrological Simulation Program in Fortran (HSPF), which was recently updated to Phase 5.3. In order to take advantage of the improvements in the Phase 5 Watershed Model, the intent is to have the model inputs fully developed in Scenario Builder. The data used to calculate the inputs to the Watershed Model – HSPF Phase 5 are finer scale and takes additional factors into consideration, such as mineralization from organic fertilizer, crop types, and double-cropping.

1.2 User-Controlled Variables

Future plans for this tool is for it to be designed so that users will have the ability to control many of the parameters. While the user interface is not yet complete, it will be designed so that users may select an area of one or more counties, the livestock types and the number of animals, along with a land use using the 25 Watershed Model-HSPF categories. Next, users will be able to alter the crop mix that is nested in each of the agricultural land uses. Best management practices (BMPs) could then be applied at the county scale. Users could select the approved Chesapeake Bay Program BMPs and efficiencies, or enter additional BMPs with their own effectiveness values. Currently, these options are reserved for the technical team, but a future version will incorporate these features for all users.

The output gives the loading of nutrients to the land and the area of soil available to be eroded. To get actual loads as delivered to the Chesapeake Bay, users must submit the data they generated in Scenario Builder to the Bay Program to run through the Watershed Model – HSPF.

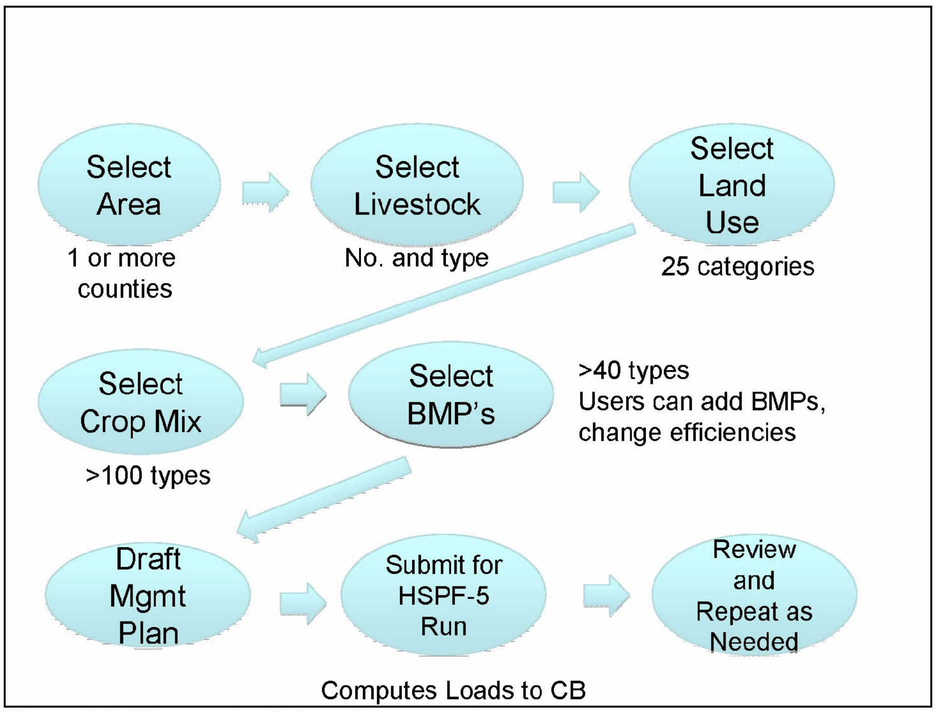

Figure 1-1: User-controlled model parameters

1.3 Process-Based Model

Scenario Builder was designed to follow the nutrient generation process from the animal through storage and application. Loss of nitrogen and phosphorus to groundwater is not considered in Scenario Builder, it is instead simulated in the Watershed Model - HSPF.

While the calculations are performed at the county scale, the processes follow what happens at a farm scale. For example, manure from various animal types is kept separate throughout the production, volatilization, storage, and application to crops' sequence. This was deliberate and allows for considerations about changes in animal types, along with species' manure that is applied to crops.

Even though the model is at a county scale or greater, specific questions may be asked if we assume a county as a single farm. This is not an optimal solution to the lack of a farm scale model, but it does provide an interim tool until such a model is available. More importantly, the consideration of farm-scale decisions in the design allows for a true process based model.

Crop growth parameters are also considered in nutrient applications. We calculate nitrogen fixation by legumes, amount of bare soil based on residue and leaf cover, and nutrient uptake by plants. Scenario Builder is designed to estimate these parameters independent of each other. The types of data and parameters used in this process-based model are listed in Figure 1-2.

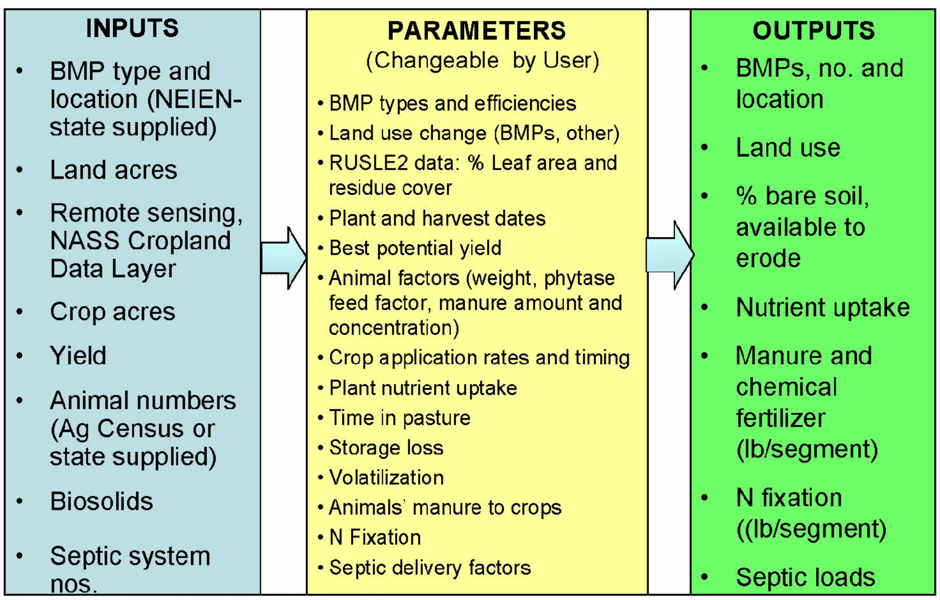

Figure 1-2: Model data relationships

1.4 Scenario Builder Output

Scenario Builder produces tabular reports of loading to land by land use and segment for the following data. Interim data products may also be made available.

- Manure and Chemical Fertilizer (lbs/acre)
- Land Use
- BMP reduction
- Plant Uptake

- N Fixation
- Bare soil % (erodible portion)
- Septic N delivery
- Scenario parameters specified by user

The manure and chemical fertilizer application are stored in two separate files of the applications by each nutrient type. Biosolids are included in the manure file. The land use output is simply the acres in each land use. An interim data product could provide acres in each crop type. The BMP reduction file is the area of land that is affected by each BMP. Plant uptake gives the amount of total nitrogen and total phosphorus taken into the entire plant (roots, and all above-ground parts) each month. The nitrogen fixation is the amount of N fixed by leguminous plants each month. The bare soil fraction is the area of soil that is not covered by residue or leaves and is available to be eroded. The amount of nitrogen from septic system drainage fields is calculated and reported as well.

The last output is the parameters, which documents the scenario parameters as specified in the user. This documentation ensures fair comparison among various scenarios.

2 AVAILABLE DATA SOURCES FOR AGRICULTURAL NONPOINT SOURCE LOADING TO THE LAND

Agricultural nutrients sources in the Nutrient and Sediment Scenario Builder are from animal manure and fertilizer. Atmospheric deposition and point sources are applied to the land outside of Scenario Builder. Loss of nitrogen and phosphorus to groundwater is accounted for in the Phase 5 Watershed Model and not in Scenario Builder.

A useful model requires reliable and credible data. Table 2-1 lists the sources of data used to estimate nutrients applied to crops, crop area, and land area. Each is discussed in the following sections.

Table 2-1: Data sources used

Source	Data	Time Period	Scale
USDA National Agricultural Statistics Service—Census of Agriculture	Animal population, Land Area, Crop Area, Yield	1982, 1987, 1992, 1997, 2002, 2007	State and county
State reported (2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State, 2002 Maryland Equine Census - Maryland Agricultural Statistics Service, 2000 New York Equine Survey - New York Agricultural Statistics Service, 2001 Virginia Equine Report - Virginia Agricultural Statistics Service, 2004 Tennessee Department of Agriculture - NASS - Equine Survey, and 2004 Delaware State Equine Survey)	Horse population	2002, 2000, 2001, 2004	County
State reported	Biosolids	1982 - 2009	County, Virginia only state to report

2.1 USDA National Agricultural Statistics Service

2.1.1 Introduction

Farm animals are a major source of non-point source nutrients. To model nutrient concentrations in the Chesapeake Bay Watershed Model, the Chesapeake Bay Program (CBP) must know the population and location of animals. The United States Department of Agriculture National Agricultural Statistics Service (NASS) produces an agricultural census twice each decade in years ending with a two or seven. The NASS Agricultural Census is conducted on a county scale and includes data on animal populations, farms, agricultural land areas, and crop yields.

The Census' land area, crop area, crop yields, and animal population inventory data are used. The data are available for the period covered in the Watershed Model, which is 1982 to present with projections into the future. Data for years in between the Censuses are interpolated. Years beyond the Censuses are projected.

Data for all years must be processed retroactively with each new Census to align the Census categories with CBP model categories and to make data among the Census years comparable despite Census changes to sampling methodology or categorization. The Census' land area is only one of several sources contributing to land use data. Land use is processed as part of the Chesapeake Bay Land Change Model for which separate documentation is available (P. Claggett, 2009).

2.1.2 Sampling Methodology Change

With each subsequent Ag census, the prior census data with revisions are reported. Data are obtained from the latest Ag census that reports any year's data. Where a category was not reported in revised data, the data from the original publication of that year's Census was obtained. There were major revisions in 2002 and only a portion of 1997 data was revised. The unrevised categories were culled from the original publication of the 1997 Census.

NASS first employed a sampling methodology in the 1982 Ag Census. Previously, the Ag Census was compiled from direct enumeration. In 2002, NASS changed its sampling methodology for the Ag census to address under reporting. NASS used statistical methods to determine where under reporting was likely, and targeted efforts to improve the response rate in those areas. NASS revised the 1997 Ag census using statistical methods to make the 1997 data comparable to the 2002 data. The categories in the revised 1997 Ag Census published in 2002 that were not adjusted and annotated as NA were those that were new categories in 2002. In these cases, the original 1997 data were used. Adjustments for the 1982, 1987, and 1992 Ag censuses are unavailable. For those years NASS recommended against making adjustments (Barbara Rater, MD NASS, personal communication, 4/14/2008 and Jim Burt, NASS National Office).

2.1.3 Data Reported as "D"

NASS withholds data that could identify any particular farm operation. Withheld data are reported as "D". When withholding one county's data could identify a farm in a neighboring county, then the neighboring county is reported as "D" also. This situation is likely to occur where there is a single large farm operation of a specific type in one county and zero farm operations of that type in the neighboring county. The NASS Census reports data on a county scale and as a state total. Data for omitted counties are combined in the Census and presented as "all other counties". Counties may report a "D" in one year, yet report in other years. Procedures for estimating a "D" value are listed.

1. A linear interpolation is made for the non-reported value between prior and subsequent Ag census years for which values were reported. This interpolation is for county and state scale. If this interpolation causes the sum of counties to be greater than the reported state values for that item in that year, then method two is used. If 30% or more of all counties in a state can not be done with this method, then proceed to method two.
2. Where there is no reported value for prior and subsequent years, then the difference between the state total and the sum of the counties is parsed between all the counties that were listed as "D". The data listed for *All Other Counties* represent the sum of the data for all counties in which data were omitted (denoted by an *N* in the electronic version of the Ag Census). Parsing of the omitted data is done in proportion to the average of the datum in that county to the state total for each year where there are reported data. This average is calculated as the ratio of the average of the item in that county for any reported years to the state total for that same year.
3. Where there is no reported state value for any Ag census year, and the state value is listed as "D", a linear regression is performed over all Ag census years.
4. Where there is no reported value for any Ag census year, then the difference between the state total and the sum of the counties is parsed in proportion to agricultural land area in the county to the state for the year in question. Agricultural land areas are from the Ag census table Farms, Land in Farms, Value of Land and Buildings, and Land Use. Items from this table include: "Total Cropland", "Pastureland and Rangeland other than cropland and woodland pastured". (When converted to Chesapeake Bay Program land uses these include pasture, degraded riparian pasture, hay with nutrients, hay without nutrients, high till without manure, high till with manure, low till with manure, nutrient management pasture, nutrient management hay, nutrient management alfalfa, nutrient management high till without manure, nutrient management high till with manure, nutrient management low till, and animal feeding operations). This is done for each year. The total of all of the counties, reported and estimated, should be no greater than the state total for the given year. If the total of all the counties is greater than the state total, and there is a county that reported zero agricultural land uses, then that county's animal population is set to zero. For land or crop areas, the counties are reduced proportionally.

Crop area and crop yield are related data and cannot be estimated independently. Where *yield is reported and acres are withheld* for a crop in a county, then the acres are estimated from the yield. The NASS Census reports yields as total yield, and not yield/acre so it is possible to estimate these acres directly from the yield. The procedures below address situations where the yields are reported and acres are withheld.

1. Determine the average yield/acre for the state from reported data for that year where pairs (acres, yield) are available. Where there are less than three values and an average may not be determined, use the average from that state among any years.
2. For areas without reported pairs, use the theoretical maximum yield for the average yield/acre.
3. Calculate state totals where not reported
4. For all pairs where acres were not reported, divide the reported yield for that county and crop type by the average yield of that crop type.
5. Check that the sum of these calculated acres equals the total reported for the acres of that crop type in the state. In each of the cases below, follow the same procedure to adjust the yields to match the state yield value.
    a. If the sum of the calculated county acres are 10% > state total and the state acre was reported, not calculated, then decrease the yield so that the calculated acres have the average yield. (Note: this assumes that the yield was incorrectly reported.) Where the state acres are exceeded, set the remaining yields and acres pairs to zero where neither acres nor yields were reported.
    b. If the calculated county acres are 10% < or > the state total and the state acre was calculated, then adjust the calculated state acres total to accommodate the calculated county acres. (Note: this assumes that the state acres were incorrectly calculated.)
    c. If the calculated county acres are 10% < state total and the state acre was reported, not calculated, then increase the county acres proportional to that area. (Note: this will result in lower than average yields.)
    d. If the acres are within 10% of the state total, then adjust the county acres to match the state acres proportional to the calculated county area.
6. For all pairs where yield were not reported, multiply the acres by the average yield to get yield
7. Should there be a yield adjustment like the acres adjustment where the calculated yields would be reduced to match the state reported yield where all counties in state have either reported yields or yields calculated in the method in step 6 immediately above, calculate the yield by multiplying the calculated acres by the average yield for all pairs missing yield. Note that this step, if necessary, would have to be done prior to acres having the withheld data estimated.

Where *both acres and yields are withheld*, then estimate acres first using the Ag Census classification for withheld data and proceed as with the scenario of acres reported and yield withheld.
Where *acres are reported but yields are withheld*, and then use the average yield/acre for the state from the same year. If the average yield can not be calculated due to less than 2

values being reported, then use the state value. If the state value is withheld, then use the theoretical maximum yield as defined in Section 5 below.

2.1.4 Interpolation

Interpolation is necessary in years the NASS Agricultural Census was not taken. These are the four years in between the Census being taken every five years. Annual data between the Agricultural Censuses is produced by interpolation using the following methodology:

Interpolated year = 1993
Agricultural Census year=1992 and 1997

1993population = 1992 population + 1 * (1997 population – 1992population) / 5

Interpolations are calculated at the county level by each item type.

2.1.5 Projection

To project data beyond the most recent NASS Agricultural Census year, a linear regression is performed. This is done at the county level by each animal type and crop. At least three reported values are used where available. If less than three values are available, then calculated data points are used.

$$\beta = \frac{N\sum xy - \sum x \sum y}{N(\sum x^2) - (\sum x)^2}$$

$$\alpha = \frac{\sum y - \beta \sum x}{N}$$

$y=\alpha + \beta x$
Calculate β first.
N=number of observations

2.1.5.1 Animal numbers

The NASS Agricultural Census animal inventory data is used in lieu of animal sales data. The inventory information from the Agricultural Census is the number of animals on the farm at the end of the year. Using the animal inventory data assumes no seasonal fluctuations in herd size and continuous replacement. This steady state assumption tends to underestimate animal numbers.

Sales data deliver a greater number of animals in some cases than inventory. To be conservative, the Chesapeake Bay Program is using the inventory data.

2.1.6 Categorization Changes among Censuses

Data types reported by the Agricultural Census have changed from one Census year to the next. Specific changes are described by specie.

2.1.6.1 Bovine Category Changes

Agricultural Census categories of "beef cattle" and "cows and heifers that have calved" directly relate to Chesapeake Bay Program (CBP) categories of beef and heifers. The 2002 Census category of other cattle encompasses what were two separate categories in previous years—"heifers and heifer calves" and "steers, steer calves, bulls, and bull calves". Years prior to 2002 add those categories together to make them comparable to the 2002 Census and CBP category of other cattle.

2.1.6.2 Poultry Category Changes

The classification of poultry changed significantly with the 2002 Census. The "pullet chicks < 13 weeks" and "pullets 13 – 20 weeks" categories were eliminated and replaced by "pullets for laying flock replacement". The "pullet 13 – 20 weeks" category had been a subcategory of layers, so this clearly conveys to the new pullet for laying replacement category. The pullet chicks < 13 weeks could have been comprised of either future layers or broilers. The CBP has assumed that all of the birds in this category grow up to be layers. NASS confirmed that this is a valid assumption (Barbara Rater, MD NASS, personal communication on 4/14/2008).

The "layers 20+ weeks" category was a subcategory prior to the revised 1997 and subsequent years. This equated directly to the new categorization. Broilers and turkeys are not split out by age group, so equate directly as well.

2.1.6.3 Swine Category Changes

The Agricultural Census categories of "Hogs and pigs for breeding" and "Other hogs and pigs" relate directly to the CBP category of "Sows" and "Hogs", respectively.

Table 2-2: Agricultural Census animal categorization changes

Species	*Watershed model phase 5 animal categories*	*Agricultural Census – County Inventory Categories*
Bovine	Beef	Beef cows – 1982, 1987, 1992, 1997, and 2002.
Bovine	Dairy	Milk cows – 1982, 1987, 1992, 1997, and 2002.
Bovine	Other cattle	Heifers and heifer calves + steers, steer calves, bulls, and bull calves – 1982, 1987, 1992, and 1997. 'Other cattle' including steers, steer calves, bulls, and bull calves category + heifers and heifer calves - 2002.
Horses	Horses	Handled separately through state supplied equine census data. 2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State Results of the 2002 Maryland Equine Census -

		Maryland Agricultural Statistics Service 2000 New York Equine Survey - New York Agricultural Statistics Service - Covers 1988 and 2000 data 2001 Virginia Equine Report - Virginia Agricultural Statistics Service 2004 Tennessee Department of Agriculture - NASS - Equine Survey 2004 Delaware State Equine Survey
Poultry	Layers	Hens and pullets of laying age – 1982, 1987, and 1992. Layers > 20 weeks – 1997 and 2002.
Poultry	Pullets	Pullet chicks and pullets < 13 weeks old + Pullets 13+ weeks, not laying – 1982, 1987, and 1992. Pullet chicks and pullets < 13 weeks old + Pullets between 13 and 20 weeks – 1997. Pullets for laying flock replacement – 2002.
Poultry	Broilers	Broilers – 1982, 1987, 1992, 1997, and 2002.
Poultry	Turkeys	Turkeys – 1982, 1987, 1992, 1997, and 2002.
Swine	Sows	Hogs and pigs for breeding – 1982, 1987, 1992, 1997, and 2002.
Swine	Hogs	Other hogs and pigs – 1982, 1987, 1992, 1997, and 2002.
Ovine	Sheep and Lambs--Inventory, Wool Production, and Number Sold	Sheep and Lambs—Inventory – 1982, 1987, 1992, 1997, and 2002.
Caprine	Milk Goats	Milk goats inventory – 1982, 1987, 1992, 1997, and 2002.
Caprine	Angora Goats	Angora goats inventory – 1982, 1987, 1992, 1997, and 2002.

Agricultural Census categories that are not included in the CBP Watershed model are shown in Table 2-3.

Table 2-3: Agricultural Census categories not included in the Watershed Model

Species	*Reason for not including*	*Agricultural Census – County Inventory Categories*

Poultry	Data pulled from a more specific Agricultural Census subcategory	Chickens 13+ weeks – 1982, 1987, and 1992.
Poultry	Data pulled from a more specific Agricultural Census subcategory	Layers and pullets 13+ weeks – 1997.
Swine	No immature swine categories are included. Specific animal numbers not listed, just number of litters.	Pig litters farrowed – 1982, 1987, 1992, and 1997.

2.1.6.4 Horses

Horse data are not directly pulled from the Agricultural Census. The horse information is culled from state-supplied data including: 2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State, Results of the 2002 Maryland Equine Census - Maryland Agricultural Statistics Service, 2000 New York Equine Survey - New York Agricultural Statistics Service - Covers 1988 and 2000 data, 2001 Virginia Equine Report - Virginia Agricultural Statistics Service, 2004 Tennessee Department of Agriculture - NASS - Equine Survey, and the 2004 Delaware State Equine Survey. These data are used for every year because no states have provided annual updates.

2.1.7 Number of Farms

The number of farms for each animal type is also taken from the Censuses (Table 2-4). The number of farms informs the acres assigned for the *Animal Feeding Operation* land use category. As with the other data from the NASS Agricultural Census, these data are selected for each county, state, and year.

Table 2-4: Agricultural Census Number of Farms

Table Name	*Item Name*	*Unit*
Cattle and calves – Inventory and Sales	Cattle and calves	no. of farms
Hogs and Pigs – Inventory and Sales	Total hogs and Pigs	no. of farms
Poultry--Inventory and Sales	Any Poultry	no. of farms
Sheep and Lambs--Inventory, Wool Production, and Number Sold	Sheep and Lambs--Inventory	no. of farms
Milk Goats	Milk goats inventory	no. of farms
Angora Goats	Angora goats inventory	no. of farms

2.1.8 Crop Data

To model nutrient applications in the Chesapeake Bay Watershed Model, the Chesapeake Bay Program must know the land area in agriculture and the types and acreage of crops. The Census' data on crop types, harvested acres and yields, farms, and agricultural land uses are obtained from the Censuses between 1982 and 2007 for the crops listed in Table

2-5. Some of the items listed are referred to as “protected area”. This denotes crops grown under glass or other protection, such as in a greenhouse. Otherwise, the crop types are grown in the open.

Table 2-5: Crops modeled in Scenario Builder

Crop name
Wheat for Grain Harvested Area
Triticale Harvested Area
Sorghum for Grain Harvested Area
Sorghum for silage or greenchop Area
Soybeans for beans Harvested Area
Sunflower seed, non-oil varieties Harvested Area
Sunflower seed, oil varieties Harvested Area
Rye for grain Harvested Area
Peanuts for nuts Harvested Area
Popcorn Harvested Area
Oats for grain Harvested Area
Mushrooms Area
Mushrooms Protected Area
Barley for grain Harvested Area
Canola Harvested Area
Corn for Grain Harvested Area
Corn for silage or greenchop Harvested Area
Buckwheat Harvested Area
Dry edible beans, excluding limas Harvested Area
Emmer and spelt Harvested Area
Escarole and Endive Harvested Area
Dry Onions Harvested Area
Eggplant Harvested Area
Cucumbers and Pickles Harvested Area
Cut Christmas Trees Production Area
Cut flowers and cut florist greens Area
Bulbs, corms, rhizomes, and tubers – dry Harvested Area
Cotton Harvested Area
Cantaloupe Harvested Area
Carrots Harvested Area
Cauliflower Harvested Area
Celery Harvested Area
Chinese Cabbage Harvested Area
Collards Harvested Area
Beets Harvested Area
Berries- all Harvested Area
Broccoli Harvested Area
Bedding/garden plants Area
Asparagus Harvested Area
Aquatic plants Area
Other nursery and greenhouse crops Area
Brussels Sprouts Harvested Area
Parsley Harvested Area
Mustard Greens Harvested Area
Nursery stock Area
Okra Area
Land in Orchards Area
Lettuce, All Harvested Area
Head Cabbage Harvested Area
Herbs, Fresh Cut Harvested Area
Honeydew Melons Harvested Area
Kale Harvested Area
Foliage plants Area
Garlic Harvested Area
Green Lima Beans Harvested Area
Green Onions Harvested Area
Potatoes Harvested Area
Potted flowering plants Area
Peas, Chinese (sugar and Snow) Harvested Area
Peas, Green (excluding southern) Harvested Area
Peas, Green Southern (cowpeas) –

Black-eyed, Crowder, etc. Harvested Area
Peppers, Bell Harvested Area
Peppers, Chile (all peppers – excluding bell) Harvested Area
short-rotation woody crops Harvest Area
short-rotation woody crops Production Area
Pumpkins Harvested Area
Radishes Harvested Area
Sweet Corn Harvested Area
Sweet potatoes Harvested Area
Spinach Harvested Area
Squash Harvested Area
Turnip Greens Harvested Area
Turnips Harvested Area
Vegetable & flower seeds Area
Snap Beans Harvested Area
Sod harvested Area
tobacco Harvested Area
Tomatoes Harvested Area
Vegetables, Mixed Area
Vegetables, Other Harvested Area
Rhubarb Harvested Area
Watermelons Harvested Area
Vetch seed Harvested Area
Timothy seed Harvested Area
Red clover seed Harvested Area
Small grain hay Harvested Area
Ryegrass seed Harvested Area
Orchardgrass seed Harvested Area
Other field and grass seed crops Harvested Area
Other haylage, grass silage, and greenchop Harvested Area
Other managed hay Harvested Area
Bromegrass seed Harvested Area
Birdsfoot trefoil seed Harvested Area
Cropland on which all crops failed or were abandoned Area
Fescue Seed Harvested Area
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area
Cropland in cultivated summer fallow Area
Wild hay Harvested Area
Pastureland and rangeland other than cropland and woodland pastured Area
Cropland used only for pasture or grazing Area
Bulbs, corms, rhizomes, and tubers – dry Protected Area
Cut flowers and cut florist greens Protected Area
Aquatic plants Protected Area
Bedding/garden plants Protected Area
Other nursery and greenhouse crops Protected Area
Nursery stock Protected Area
Greenhouse vegetables Area
Greenhouse vegetables Protected Area
Foliage plants Protected Area
Potted flowering plants Protected Area
Sod harvested Protected Area
Vegetable & flower seeds Protected Area
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area
Alfalfa Hay Harvested Area
Alfalfa seed Harvested Area
Turf grass

2.1.8.1 Obtaining Data from the NASS Agricultural Census

Land area data are obtained to give the total area classified as agricultural. Crop data are obtained to determine crop yields and crop areas. There may be more crop acres than land acres because each acre of land may have more than one crop planted and harvested during a year; this is termed double cropping. Chapter 1 of the Census is state-scale data and Chapter 2 is county-scale data. The states that are modeled include: New York, Pennsylvania, Delaware, Maryland, District of Columbia, West Virginia, Tennessee, and North Carolina. Tennessee and North Carolina are included even though they don't drain to the Bay because the Bay Program models the southern rivers of Virginia.

2.1.8.2 Categorization changes over time

Item names change among census years. Specific actions to address these changes are described in Table 2-6. Some data items selected from different tables are identical. Selecting both items allows for validation. In other cases, state aggregated data are selected as well as county level data. This is to inform the calculation of withheld data values. Some crops are listed in one state's census but not in another because certain crops are not present in all states.

Table 2-6: Agricultural Census crop categorization changes

Agricultural Census Item Name	*Chesapeake Bay Program item name*	*Categorization Action*
Cropland idle, cover crops or soil improvement but not harvested and not pastured or grazed	Cropland idle, cover crops or soil improvement but not harvested and not pastured or grazed	Combined the two categories from the Census of "cropland idle" with "cover crops or soil improvement but not harvested and not pastured or grazed"
Cut Christmas Trees	Cut Christmas Trees	Data only available from 2002
Flower seeds, vegetable seeds	Flower and vegetable seeds	Combined with vegetable seeds in 1997 and 1992 and 1987 and 1982 for some states. Summed 2002 flower and vegetable seed categories
Sunflower seed-oil, sunflower seed-non-oil	Sunflower seed (all)	In years where there was no oil vs. non-oil varieties all was used as non-oil
Wild hay	Managed hay	Renamed

2.1.8.3 Turf grass

See section 7.6.

3 CALCULATION OF AVAILABLE NITROGEN AND PHOSPHORUS FOR APPLICATION TO THE LAND

The nutrient sources that are considered in the Scenario Builder include animals, inorganic fertilizer, septic, and land-applied biosolids. Each is discussed in the following sections. Other contributions of nutrients modeled in the Chesapeake Bay Program's Watershed Model-HSPF include atmospheric deposition and point sources. These data are produced by data analysis systems separate from the Scenario Builder.

3.1 Animals

The animal units are determined by the average number of animals making up 1,000 lbs of that animal type. To calculate this, the average live weight of each animal type is required. The methodology for determining the live animal weight uses the amount of manure produced, and then back calculates to the average live animal weight (Kellogg 2000; Agricultural Waste Management Field Handbook, Moffitt and Lander 1997, Moffitt and Alt 1998). The average live weight is the average of the animals at any age in that category. For example, pullets are defined by NASS as less than 20 weeks of age, so the live animal weight is the average of a pullets' weight during those 20 weeks. Animal units are calculated for each animal type as:

Animal Units = 1000 lbs / avg. weight of animal

Turkey weights are the average weight at slaughter split equally among hens and toms rather than the average over the growing period (Kellogg, 2000). Source information on horse weights and manure are from the USDA-NRCS National Engineering Handbook Part 651, Agricultural Waste Management Field Handbook. Animal weights were set for sheep and lambs as 100 lb, angora goats as 65 lbs, and milk goats including kids as 65 lbs (S. Schoenian, Sheep 201, Sheep & Goat Specialist, Maryland Cooperative Extension). The Agricultural Census does not categorize meat goats, which are prominent in the Mid-Atlantic region (S. Schoenian, personal communication, 2008). Thus, the primary goat type is not considered by the NASS Agricultural Census data, which may lead to an underrepresentation of this animal type.

The 2002 Census defines "other cattle" as: heifers, steers, bulls 500 lbs+, and all calves less than 500 lbs. Using Kellogg (2000), the average for other cattle is 2.08 animals/animal unit. This weight and the amount of manure produced were derived by averaging the following:

- beef calves from calving to about 500 lbs, 4 animals/au
- beef heifers for replacement herds, 1.14 animals/au
- beef breeding herds (cows and bulls), 1 animal/au
- beef stockers and grass fed beef, 1.73 animals/au
- dairy calves from calving to about 500 lbs, 4 animals/au

- dairy heifers for replacement herds, 0.94 animals/au
- dairy stockers and grass fed animals marketed as beef, 1.73 animals/au

This average was used because each state has a different mix of the animals that are in the "other" category. Weighting toward any one type creates an unfair bias toward a particular state or region. Weighting also creates a static variable eliminating the possibility of fluctuation over time.

The pullets' category includes those less than 13 weeks of age and also those between 13 and 20 weeks. These categories were separated in censuses prior to 2002. Average animals per animal unit for these categories are 250 pullets for those between 13 and 20 weeks and 455 pullets for those less than 13 weeks. The average of these two is 352.5 and is used for the combined pullets category.

These data were found to be comparable with the Virginia Nutrient Management Standards and Criteria, Revised October 2005, Virginia Department of Conservation and Recreation.

Table 3-1: Animal types, animal units, and pounds of manure/day/animal unit

Animal type	*Live animal weight (lbs)*	*No. of animals per animal unit (animal unit=1000 lbs)*	*Manure (lbs) per day per animal unit*	*Animal weight and manure (lbs) data source*
beef	877.19	1.14	58	Kellogg et. al. (2000)
dairy	1351.35	0.74	86	Kellogg et. al. (2000)
other cattle	480.77	2.08	64.39	Kellogg et. al. (2000)
broilers	2.20	455	85	Kellogg et. al. (2000)
layers	4.00	250	64	Kellogg et. al. (2000)
pullets	2.84	352.5	45.56	Kellogg et. al. (2000)
turkeys	14.93	67	47	Kellogg et. al. (2000)
hogs and pigs for breeding	374.53	2.67	33.46	Kellogg et. al. (2000)
hogs for slaughter	110.01	9.09	84	Kellogg et. al. (2000)
horses	1000.00	1	51	USDA-NRCS National Engineering Handbook Part 651, Agricultural Waste Management Field Handbook
angora goats	65.02	15.38	41	Schoenian (2008)
milk goats	65.02	15.38	41	Schoenian (2008)
sheep and lambs	100.00	10	40	Schoenian (2008)

The number of animals in each category except horses comes directly from the 5-year NASS Agricultural Censuses. The horse data came from state-sponsored censuses ranging from 2000-2004. The NASS Agricultural Census data does collect data on horses and ponies, but this information is typically completed only by farmers who use horses and ponies as work animals. This leaves out all pleasure horse farms and racehorse training and breeding operations. It is the pleasure horses and racehorses that comprise the majority of horses in many parts of the watershed, so these numbers must be gathered from other sources.

3.2 Inorganic Fertilizer

In the Scenario Builder, fertilizer sales data were consulted for comparison purposes only. The fertilizer sales data are prepared by the Association of American Plant Food Control Officials based on fertilizer consumption information submitted by state fertilizer control offices. The consumption data include total fertilizer sales or shipments for farm and non-farm use. Liming materials, peat, potting soils, soil amendments, soil additives, and soil conditioners are excluded. Materials used for the manufacture or blending of reported fertilizer grades or for use in other fertilizers are excluded to avoid duplicate reporting.

The fertilizer sales data were not used directly due to complications with consistency of reported data throughout the modeled time period and region. In addition, there are several major ports in the Chesapeake Bay Watershed. Fertilizer may be sold at the port and transferred to another region for resale, which could result in double counting these sales.

3.3 Biosolids

Land-applied biosolids can be a significant source of nutrients on farm land. The Chesapeake Bay Program requested that each state submit data on the use of biosolids used as a fertilizer. Virginia submitted such data for the modeled period of 1982-2009. These data were in units of dry tons/year. Some data were received from Maryland, but these data were in wet tons. Maryland was unable to provide information on how to convert from wet to dry tons for each biosolids provider. A general assumption of moisture content was unacceptable to Maryland, so this data could not be used.

4 ACCOUNTING FOR NITROGEN AND PHOSPHORUS LOSSES AND TRANSFORMATIONS

Methods for calculating the nutrient speciation, volatilization, and storage and handling loss for organic and inorganic fertilizer, and manure directly excreted onto pasture are discussed in the following sections.

4.1 Nutrient Speciation

The forms of nitrogen and phosphorus that are modeled in the Scenario Builder were established to mirror those in the Chesapeake Bay Program's Watershed Model-HSPF with the addition of mineralized forms of nitrogen and phosphorus. Since the amount of manure applied to crops is generally calculated by farmers to include only the plant-available portion, we included the mineralized forms. These mineralized forms are the conversion of organic N to NH_4. The mineralization process liberates plant-available N. While the nutrient NH_3 is written and referred to as such, it is generally used to represent both NH_3 and NH_4 in the Scenario Builder and Watershed Model-HSPF lexicon. Nutrients modeled in the Scenario Builder include:

1. NH_3
2. Organic N
3. Mineralized N
4. NO_3
5. PO_4
6. Organic P
7. Mineralized P

4.1.1 Inorganic Fertilizer

The amount of nitrogen and phosphorus are independent of each other for inorganic fertilizer. The speciation was set at the most commonly perceived mixture since fertilizer sales data could not be analyzed for this purpose (Chesapeake Bay Program, Agricultural Nutrient and Sediment Workgroup, 2008). The nitrogen component of inorganic fertilizer is comprised of NH_3 and NO_3. NH_3 is 75% and NO_3 is the other 25% of total N. All of the phosphorus is found in the form of PO_4.

4.1.2 Organic Fertilizer

Organic fertilizer sources include animal manure and biosolids. In organic fertilizer, N and P are linked, since a farmer does not chemically separate the various forms. The total mass of manure per day per animal unit is split into total N and total P for each animal species (Table 4-1). Goat waste is assumed to have the same proportion of nutrients as sheep waste. The category 'other cattle' is an average like in Section 3.1.

Table 4-1: Nutrient content of animal manure and biosolids (ASAE, 2003)

Source types	*Nutrient*	*lb-Nutrient/lb manure*

angora goats	TN	0.0110
Beef	TN	0.0059
Biosolids	TN	0.0390
Broilers	TN	0.0129
Dairy	TN	0.0052
hogs and pigs for breeding	TN	0.0066
hogs for slaughter	TN	0.0062
Horses	TN	0.0059
Layers	TN	0.0131
milk goats	TN	0.0110
other cattle	TN	0.0037
Pullets	TN	0.0136
sheep and lambs	TN	0.0105
turkeys	TN	0.0132
angora goats	TP	0.0027
beef	TP	0.0016
biosolids	TP	0.0250
broilers	TP	0.0035
dairy	TP	0.0011
hogs and pigs for breeding	TP	0.0021
hogs for slaughter	TP	0.0021
horses	TP	0.0014
layers	TP	0.0047
milk goats	TP	0.0027
other cattle	TP	0.0010
pullets	TP	0.0053
sheep and lambs	TP	0.0022
turkeys	TP	0.0049

Total N is further broken into NH3, organic N, and mineralized N. NO_3 is not present in animal wastes in measurable amounts (Kellogg et al. 2000). TN, NH_3, TP, and PO_4 values were taken from ASAE standards (2003). Organic N and P are determined as:

$$TN-NH_3=ORG\ N$$
$$TP-PO_4=ORG\ P$$

Where values are not specified data from the most similar animal species are used (Table 4-2).

Table 4-2: Animal type used for specific nutrients if specified animal type data unavailable

Animal type missing nutrient fraction	*Animal type used*	*Nutrient type(s)*
goats	beef	Org N
other cattle	beef	Org N
sheep	beef	Org N
broilers	layers	NH_3
pullets	layers	NH_3
turkeys	layers	NH_3
goats	sheep	Org P and PO_4
Horses	swine	Org N

The calculation of mineralized N uses typical values for spring or early fall land applied manure; (Table 4-3). N mineralization factors for bovine, swine and poultry were taken from the Mid-Atlantic Nutrient Management Handbook, February 2006, originally cited from VaDCR, 2005. Though temperature, water content, drainage features, and organic carbon all have an impact on mineralization; these factors are not considered in this estimation. Mineralized N is calculated as:

Mineralized N = Mineralization factor * Original Organic N

Organic N is then retroactively adjusted as:

Organic N = Original Organic N – Mineralized N

Plant available phosphorus is conserved in the soil, so all organic P is assumed to be biologically available.

Table 4-3: Nutrient mineralization factors

Animal type	*Phosphorus Mineralization factor*	*Nitrogen Mineralization factor*
bovine	1	0.35
swine	1	0.50
poultry	1	0.60
horses	1	0.50
sheep, lambs, and goats	1	0.35

The quantity of species of each nutrient can be found by:

Mass of nutrient=(mass of waste / animal unit / unit of time) * (lb nutrient/lb manure)

4.1.3 Phytase Feed Additive

Phytase is an enzyme added to poultry-feed that helps poultry absorb phosphorus. The addition of phytase to poultry feed allows more efficient nutrient uptake by poultry, which in turn allows decreased phosphorus levels in feed and less overall phosphorus in poultry waste. The use of phytase is a best management practice (BMP). In Scenario Builder, no poultry automatically have the phytase feed additive. The values of implementation are reported by the Chesapeake Bay jurisdictions each year as part of their annual progress reports.

4.2 Volatilization

Volatilization rates are calculated as the amount of NH_3 that moves into the atmosphere from stored manure. Ammonia volatilization is highly variable and literature suggests values that range from 0 to 40%. Numerous factors affect the volatilization rate including, but not limited to, temperature, moisture, and pH.

In Scenario Builder, volatilization is not calculated for directly excreted manure or for manure once it is applied to the land. Volatilization for direct excretion and land-applied manure is handled by the Watershed Model, which uses rates based on temperature and hydrology.

Ammonia volatilization in inorganic fertilizer varies by factors other than just the type or composition of inorganic fertilizer. Therefore, there is also no volatilization for inorganic fertilizer calculated in Scenario Builder.

Volatilization data will be reconciled with the atmospheric deposition model in the next version of Scenario Builder.

The volatilization rates have been used in the previous versions of the Watershed Model-HSPF and were not changed when incorporated into the Scenario Builder (Table 4-4). Sheep, lambs and goats are new animal types; they are given the same volatilization rates as cattle since all of those animal species are ruminants (S. Schoenian, personal communication 2008).

Table 4-4: Volatilization rates of ammonia from nutrient sources

Source name	***Fraction not volatilized***
pullets	0.43
turkeys	0.43
hogs and pigs for breeding	0.19
beef	0.35
broilers	0.43
Heifers (cows and heifers that have	0.35

calved)	
hogs for slaughter	0.5
horses	0.68
layers	0.43
other cattle	0.35
sheep and lambs	0.35
angora goats	0.35
milk goats	0.35
biosolids	0.4875

4.3 Animal confinement (% time in pasture)

The amount of time an animal is in pasture determines the amount of manure directly excreted on pasture. In the Scenario Builder model, animals are always in one of two locations while alive, in a pasture or an animal production area. Chesapeake Bay Program Watershed Model-HSPF pasture land uses include: pasture, nutrient management pasture, or trampled riparian buffer. The animal production area land use is named the 'animal feeding operation' or AFO.

The amount of time animals are in pasture varies by the animal type and the region of the watershed. Table 4-5 lists the fraction of time each animal is in pasture based on the region of the watershed. Region descriptions are in Section 5.

While animals may be turned out to fields to forage after a crop is harvested, the length of time is typically only a few days (Doug Goodlander, PA DOE, personal communication, 2008). While the animal is foraging, they may excrete manure. This excreted manure is not captured in this model. In Virginia, this practice occurred primarily in the Shenandoah Valley (specifically in Augusta and Rockingham Counties). According to staff in the valley, that practice is fading out and need not be addressed by Scenario Builder (William Keeling, VA DCR, personal communication, 2008).

Should there be no pasture land in a county, then Table 4-5 is not relevant; rather the Scenario Builder classifies the animals as 100% confined and all manure is considered stored and available for distribution to row crops.

The amount of nutrients applied directly to pasture for each animal type by county is calculated as:

1. Number of animals * fraction of time in pasture
2. Convert to animal unit (process previously described in Section 3.1)
3. Determine mass of manure in terms of N and P forms (process previously described in Section 4.1.2)

The land use of trampled riparian pasture receives nine times the amount of nutrients the other two pasture components receive in each county.

Table 4-5: Fraction of time animals are in pasture by animal type and region

Animal	*Growth_reg*	*% Time in Pasture*										
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Angora Goat, Milk Goat	DE_1, MD_2	0	0.5	1	1	1	1	1	1	1	1	1
	MD_1, MD_3, NY_1, PA_1, PA_2, PA_3	0	0	0	0	1	1	1	1	1	1	0
	VA_1, VA_2, VA_3	0.8	0.8	1	1	1	1	1	1	1	1	1
	WV_1	0	0	0.5	1	1	1	1	1	1	1	0
Sheep and lambs	DE_1, MD_2	0	0.5	1	1	1	1	1	1	1	1	1
	MD_1,PA_3	0	0	1	1	1	1	1	1	1	1	1
	VA_3	0.8	0.8	1	1	1	1	1	1	1	1	1
	MD_3, PA_1, PA_2	0	0	0	1	1	1	1	1	1	1	1
	NY_1	0	0	0	1	1	1	1	1	1	1	0
	VA_1, VA_2	1	1	1	1	1	1	1	1	1	1	1
	WV_1	0	0	0.5	1	1	1	1	1	1	1	0
Other Cattle	DE_1, MD_2, WV1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	MD_1, PA_3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	MD_3, PA_1, PA_2	0.75	0.75	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	NY_1	0	0	0	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0
	VA_1, VA_2	1	1	1	1	1	1	1	1	1	1	1
	VA_3	0.8	0.8	1	1	1	1	1	1	1	1	1
Beef Heifers	DE_1, MD_1, MD_2, PA_3, VA_1, VA_2	1	1	1	1	1	1	1	1	1	1	1
	MD_3, PA_1, PA_2, WV_1	0	0	1	1	1	1	1	1	1	1	1
	VA_3	0.8	0.8	1	1	1	1	1	1	1	1	1
	NY_1	0	0	0.25	1	1	1	1	1	1	1	0.5
Dairy Heifers	DE_1, MD_2, VA_1, VA_2, VA_3, WV_1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	MD_1, PA_1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	MD_3, PA_1, PA_2	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	NY_1	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0

Broilers, Layers	DE_1, MD_1, MD_2, MD_3, PA_1, PA_2, PA_3, VA_1, VA_2, VA_3, WV_1	0	0	0	0	0	0	0	0	0	0	0
	NY_1	0	0	0	0	0.45	0.45	0.45	0.45	0.45	0.45	0
Pullets, Hogs and pigs for breeding, hogs for slaughter	DE_1, MD_1, MD_2, MD_3, NY_1, PA_1, PA_2, PA_3, VA_1, VA_2, VA_3, WV_1	0	0	0	0	0	0	0	0	0	0	0
Turkeys	DE_1, MD_1, MD_2, MD_3, PA_1, PA_2, PA_3, VA_1, VA_2, VA_3, WV_1	0	0	0	0	0	0	0	0	0	0	0
	NY_1	0	0	0	0	0.65	0.65	0.65	0.65	0.65	0.65	0
Horses	DE_1, MD_2, PA_1, PA_2, PA_3, WV_1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	MD_1, PA_3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	MD_3, PA_1	0.6	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	NY_1	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3

4.4 Manure Storage and Handling Residual

Loss of manure and other nutrient sources occurs during storage due to physical processes. The physical loss occurs when some manure falls out of the bucket of a front-end loader, leaks out of a spreader in unintended locations, or inadvertently slips off a concrete pad where it is stored. However, storage loss is most common when manure is absorbed or incorporated into the soil in animal concentration areas (Doug Goodlander, PA DEP, personal communication, 2008).

Storage loss will vary by animal type, since management practices associated with animal concentration areas and storage facilities vary by animal type. *Storage loss does not account for the type of storage system used on any particular farm or the angle of repose for dry heaps of manure.* Rather, storage loss applies the average annual loss across the dominant storage systems in use throughout the simulation period.

For all poultry and swine, 15% of manure is lost during storage. For beef, dairy, sheep and lambs, goats, and horses, 20% is lost (CBP Watershed Technical Workgroup and CBP Agricultural and Nutrient Sediment Reduction Workgroup approval, 2008).

The mass of nutrients lost during storage and handling is applied to the land use that includes the animal production area (animal feeding operation, or AFO).

4.5 Estimating Detached Sediment

The purpose of the detached sediment logic is to determine the increase in the monthly amount of erodible sediment by Phase 5 land use (post-bmp) for a Land Segment in a given year. See detached sediment requirements in section 10.8.

5 ACCOUNTING FOR SPATIAL AND TEMPORAL VARIATION IN AGRICULTURAL PRACTICES

Nutrient application amount and timing is governed by the following principles:

- Temperature zone variations
- State nutrient management and land grant university cooperative extension recommendations
- Regional management practices
- Actual yield history, from the NASS Agricultural Census

To introduce spatial variability, the construct of growing regions was created. Each state is established as its own region to accommodate variations in state-recommended nutrient application rates and timing. The three largest states—Virginia, Maryland, and Pennsylvania—are each classified further into three smaller regions. This further classification into growing regions allows for variation among planting and harvest dates based on typical last frost and first killing frost.

Modeled agricultural variables include plant and harvest dates, nitrogen fixation, bare soil cover, plant nutrient uptake, nutrient application rate, and nutrient application timing. These agricultural practices are modeled where each year is independent of the previous or subsequent year. While this seems counter-intuitive based on how a farmer operates, it holds true to the scale of the source data and avoids making assumptions which would only introduce error.

The classifications of the growing regions, temporal scale, and agricultural practice data are discussed separately in the following sections.

5.1 Growing Regions

There are twelve growth regions in the Chesapeake Bay Watershed. Each state is necessarily its own region, since there are separate crop management and nutrient guidelines for each state. Where the agronomy guide from each state divided the state into different growing regions, then those regions were used. Where the guides did not make a distinction, the 1990 USDA Hardiness Zone delineations were used to see if the state should be divided. The more recent 2003 hardiness zones were not used since it is considered unlikely that farmers changed planting dates and 1990 is closer to the mid-point of the modeled period (1982 – 2005). The USDA Hardiness Zone boundaries are set where there is a 10° Fahrenheit difference in the average annual temperature. The lines were established by comparing multiple maps and determining which counties fell into which regions. Boundary lines were shifted to match county lines. Specifically:

- In New York, the portion of the state that lies in the watershed is primarily the central part, which the Cornell Ag Guide considers one region.
- In Pennsylvania, the Agronomy Guide divides the state into separate growing regions for each crop; however, the lines of the regions are very similar to each other and to the lines of USDA Hardiness Zones. Therefore, it was determined that Pennsylvania would be divided into three regions that follow the boundaries given in the Agronomy Guide: Zone 1, Zone 2 and Zone 3.
- In West Virginia, the portion of the state that lies in the watershed was in a single USDA Zone, so WV has one region.
- Maryland's Nutrient Management Manual does not divide the state; however, there are two USDA Zones. Therefore, MD was divided into USDA Zone 6 and USDA Zone 7. Concern arose that this left an eastern shore county in the same zone as a Western Maryland county and were thus subject to the same conditions. To address this concern, a third zone, "Western MD" was added that includes Garrett, Allegheny and Washington counties.
- Delaware also falls into one USDA Zone, and was therefore left undivided.
- Virginia's Agricultural Guide divides the state into three sections that roughly follow geologic provinces: Eastern, Piedmont and West of Blue Ridge.
- North Carolina and Tennessee counties follow physiographic provinces.

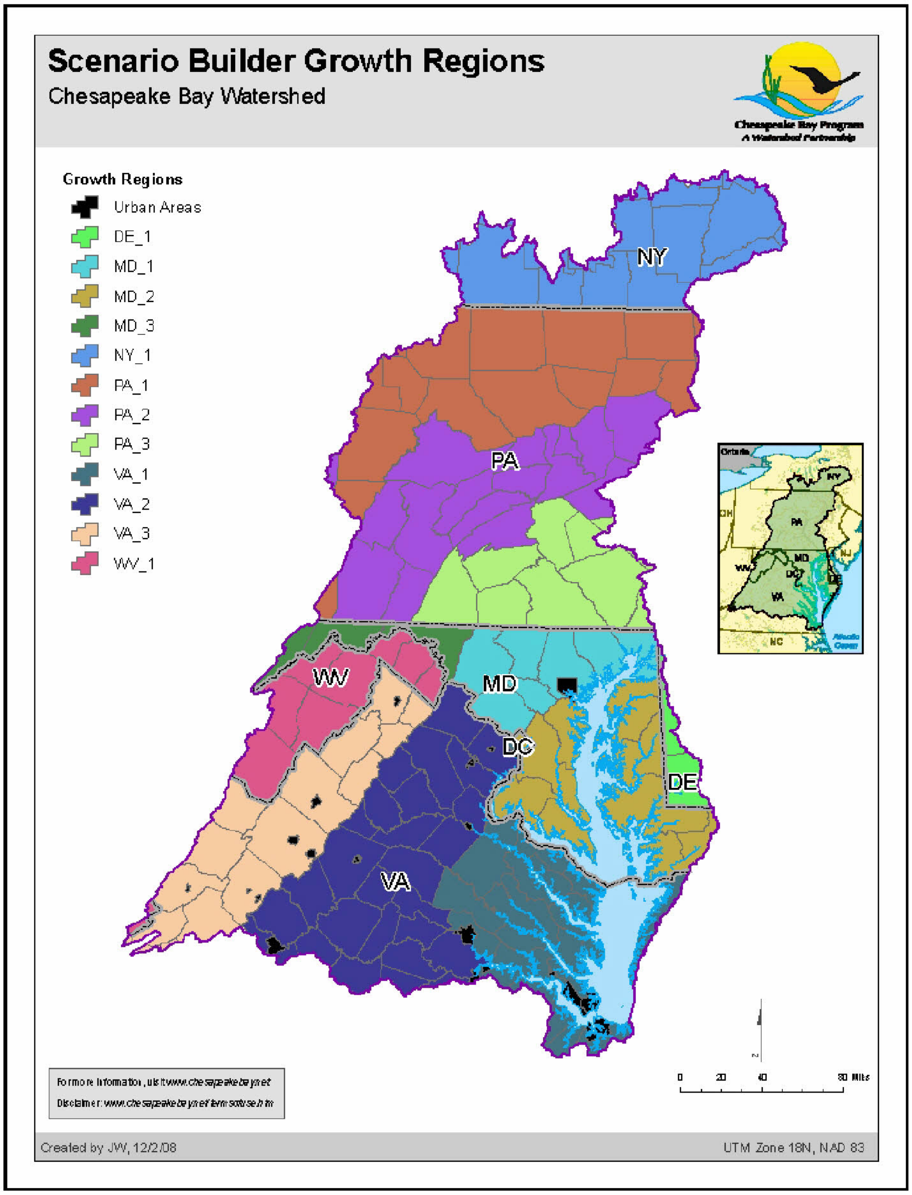

Figure 5-1: Growing Regions

USDA Hardiness Zones were incorporated into the identification of the regions to make it possible to relate data on planting and harvesting dates in one state to another state. The guides in Maryland, Delaware and West Virginia only report recommended nutrient application rates, not dates. If a region in one of these states corresponds to a region in another state that lies in the same USDA Hardiness Zone, it was assumed that the planting and harvesting dates would be similar for both of those regions. For example, the dates for Eastern VA were also used for MD Zone 2 and Delaware because all three lie in USDA Zone 7.

While source data was initially prepared using growing regions, it is stored at the county scale. This has allowed more precision as source data is fine-tuned to the county level.

5.2 Temporal Scale

Data is calculated on a monthly time scale. Much of the source data is taken from the National Agricultural Statistics Service's (NASS) Agricultural Census and is from the years 1982, 1987, 1992, 1997, 2002, and 2007. Years between Agricultural Census years and those in the future are interpolated or projected using a linear regression per Section 2.1.4.

5.3 Agricultural Practices

Scenario Builder uses agricultural practice information only to determine the timing of nutrient application and the amount of nutrients required. Scenario Builder does not have temperature or rainfall data and is not designed to be a full crop growth model. For this reason, few of the crop parameters are linked. (For example, uptake and nutrient application are calculated independently.)

Crop-related data include plant and harvest dates, nitrogen fixation, bare soil cover, crop yields, plant uptake, nutrient application rates, and nutrient application timing. Each of these parameters is discussed separately in the sections below.

5.3.1 Plant and harvest dates

Plant and harvest dates are used to inform the timing of plant uptake, nitrogen fixation, and nutrient application. Uptake and nitrogen fixation can only occur when the plant is growing. The days between the plant and harvest date define this growing time. A single plant and harvest date is used for each crop or plant type in each growth region.

Having only a single date for planting and harvesting is problematic for double cropping and crops such as vegetables, which are planted and harvested multiple times in a single season, or hay and alfalfa, which are harvested multiple times in a single season. The need to incorporate multiple plant and harvest dates is a known issue and will be incorporated in a future phase of the model development. Currently, the first plant and last harvest date is used for hay and alfalfa and the last plant and harvest dates are used for vegetables.

Scenario Builder's calculations are performed on a county scale and use the most typical plant and harvest dates at that scale. While it is commonly understood that there is variation among plant and harvest dates among farmers, the spatial scale of this model is at the county and can not accommodate farm-scale variation.

First and last frost dates were used as a guiding parameter for the plant and harvest dates. Agronomy guides for each state frequently base planting and harvesting dates on the last frost in the spring and the first frost in the fall. In order to determine those dates for each growing region, the "Freeze/Frost Data" from the National Climatic Data Center

(CLIM20) was used. This publication lists the frost dates for numerous sites within each state in the United States at various probability levels. Using five monitoring sites within the watershed in each of the 12 growing regions, the 50% probability level was used. Then the midpoint of the range among the five sites in each growing region was used (Table 5-1).

Table 5-1: First and last frost dates for each growing region

Growing Region	*Last Frost*	*First Killing Frost*
DE 1	April	October
MD 1	April	October
MD 2	April	October
MD 3	April	October
NY 1	May	October
PA 1	May	October
PA 2	May	September
PA 3	April	October
VA 3	May	October
VA 2	April	October
VA 1	April	November
WV 1	May	October

Most planting and harvest dates are given as a range for each crop in each state's agronomy guide. Sometimes a season alone was given as a planting or harvest range. Sometimes harvest dates were not given at all. Rules that applied where the planting and harvest dates are not expressly stated in the agronomy guide are as follows:

- Spring and fall dates were assumed the true range of spring and fall. If a guide referred to early spring, the range of dates for the first half of spring was used in lieu of the midpoint. Likewise, late spring referred to the second half of spring. Early fall referred to the first half of fall and late fall referred to the second half of fall. Since Scenario Builder is at a monthly scale, these typically fell in the same month as the midpoint.
- Where the guides gave a choice of plant dates, the first was used.
- If the crop or plant type is a perennial, the plant date corresponds to emergence and the harvest date corresponds to the killing frost.
- If the guide did not provide planting and harvest dates at all, then the dates are used for an adjacent region. For example, Maryland's eastern shore (MD 2) could be used for Delaware (DE 1).
- Frequently harvest times were specified in terms of stages of maturity. In those cases, a variety of sources was consulted to estimate the time taken to reach the indicated maturity stage. Sources include Cooperative Extension factsheets, and variety trials. Zadok's growth stages were used where possible.

- Where data were unavailable from state agronomy or nutrient management guides, then the crop cover canopy estimates generated from RUSLE 2 were consulted.
- For green lima beans in Delaware, the plant and harvest dates were taken from the RUSLE 2 data for snap beans
- Vegetable planting dates were taken from http//www.hgic.umd.edu/_media/documents/hg16_000.pdf.

5.3.2 Nutrient application timing and fraction

Each state issues recommendations for nutrient application rates and timing. These recommendations were used for the fraction of nutrients applied on each crop at a particular time. For example, split application to corn may be 50% of the total nutrients applied 20 days prior to planting and 50% applied 60 days after planting. This section discusses how the data are used and the data generalizations.

The state recommendations for application timing were used for all crops; including those under a nutrient management plan as well as those without a plan (Penn State Agronomy Guide 2009-2010, University of Delaware Soil Testing Program Nutrient Guidelines, consulted on-line 2008-2009, Virginia Cooperative Extension Agronomy Guide 2000, Maryland Cooperative Extension Soil Fertility Management-1 2002, Nitrogen Guidelines for Field Crops in New York 2003). Nutrient application timing (as well as rates, form, and methods) may vary between farmers using a nutrient management plan as opposed to those farmers without a plan. However, specific dates can only be defined if there is a consistent behavior among a specific set of farmers. That is, if farmers not under a nutrient management plan always applied nutrients all at once, or always at inopportune times, such as in the winter when crops may not be actively growing, then those dates could be specified for crops not under nutrient management. We were unable to define a consistent behavior among farmers without a nutrient management plan. Thus, the nutrient application timing does not vary according to nutrient management planning. In contrast, the nutrient application rate does vary between nutrient management and non-nutrient management.

5.3.2.1 Theoretical nutrient uptake

Meisinger and Randall (1991) and Lander (2009) reported nutrient uptake values for several crops. Uptake values were estimated only for the harvested part and do not consider crop residue and roots as a part of the harvest material. Nutrient uptake is reported in pounds per yield unit (bushel, tons, etc.) per acre.

According to Sullivan et al. (1999), one quarter or one third of the amount of nitrogen found in the portion of the crop above the ground usually is present in the roots, and for annual crops, most of the N present in roots moves to plant tops maturity. Sullivan et al. (1999) reported that 75 to 95% of nitrogen uptake belongs to the portion of the crop above the ground. The theoretical uptake was calculated multiplying nutrient uptakes found in the literature by 1.17 (85% of nitrogen is in the portion of the crop above the ground). The theoretical uptake accounts for the N uptake of whole plant (Table 4). For crops with yield and uptake data unavailable, a yield unit of 1 and the median nutrient uptake of all the crops found in the literature were used.

Table 5-2. Theoretical nutrient uptake.

Crop Name	*Nitrogen pounds per yield unit*	*Phosphorus pounds per yield unit*	*Yield unit*	*Source*
Alfalfa Hay Harvested Area	59.516	8.927	dry tons	Meisinger, 1991
Alfalfa seed Harvested Area	0.511	0.058	pounds	NRCS
Asparagus Harvested Area	11.647	1.747	tons	Meisinger, 1991
Barley for grain Harvested Area	1.059	0.212	bushels	NRCS
Beets Harvested Area	7.059	1.059	tons	Meisinger, 1991
Birdsfoot trefoil seed Harvested Area	0.251	0.038	pounds	Meisinger, 1991
Broccoli Harvested Area	16.471	2.471	tons	Meisinger, 1991
Bromegrass seed Harvested Area	0.387	0.066	pounds	NRCS
Buckwheat Harvested Area	1.012	0.188	bushels	NRCS
Canola Harvested Area	0.041	0.007	pounds	NRCS
Cantaloupe Harvested Area	4.000	0.600	tons	Meisinger, 1991
Carrots Harvested Area	4.824	0.724	tons	Meisinger, 1991
Cauliflower Harvested Area	10.588	1.588	tons	Meisinger, 1991
Corn for Grain Harvested Area	0.976	0.146	bushels	Meisinger, 1991
Corn for silage or greenchop Harvested Area	10.235	1.535	tons	Meisinger, 1991
Cotton Harvested Area	20.329	3.049	bales	Meisinger, 1991
Cucumbers and Pickles Harvested Area	3.412	0.512	tons	Meisinger, 1991
Dry edible beans, excluding limas Harvested Area	4.824	0.724	cwt	Meisinger, 1991
Dry Onions Harvested Area	5.882	0.882	tons	Meisinger, 1991
Emmer and spelt Harvested Area	1.129	0.224	bushels	NRCS
Fescue Seed Harvested Area	0.404	0.082	pounds	NRCS
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	23.529	3.529	green tons	Meisinger, 1991
Head Cabbage Harvested Area	6.941	1.041	tons	Meisinger, 1991
Land in Orchards Area	28.235	4.235	tons	Meisinger, 1991
Lettuce, All Harvested Area	5.765	0.865	tons	Meisinger, 1991
Oats for grain Harvested Area	0.812	0.122	bushels	Meisinger, 1991
Orchardgrass seed Harvested Area	0.412	0.041	pounds	NRCS
Other field and grass seed crops Harvested Area	0.387	0.066	pounds	NRCS
Peanuts for nuts Harvested Area	0.047	0.004	pounds	NRCS

Peas, Chinese (sugar and Snow) Harvested Area	37.647	5.647	tons	Meisinger, 1991
Peas, Green (excluding southern) Harvested Area	37.647	5.647	tons	Meisinger, 1991
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	37.647	5.647	tons	Meisinger, 1991
Peppers, Bell Harvested Area	5.059	0.759	tons	Meisinger, 1991
Peppers, Chile (all peppers – excluding bell) Harvested Area	0.253	0.038	cwt	Meisinger, 1991
Potatoes Harvested Area	0.588	0.088	cwt	Meisinger, 1991
Red clover seed Harvested Area	0.494	0.058	pounds	NRCS
Rye for grain Harvested Area	1.412	0.212	bushels	Meisinger, 1991
Ryegrass seed Harvested Area	0.329	0.066	pounds	NRCS
Small grain hay Harvested Area	37.647	5.271	dry tons	NRCS
Snap Beans Harvested Area	10.588	1.588	tons	Meisinger, 1991
Sorghum for Grain Harvested Area	1.153	0.212	bushels	NRCS
Sorghum for silage or greenchop Area	17.365	2.871	tons	NRCS
Soybeans for beans Harvested Area	4.176	0.424	bushels	NRCS
Spinach Harvested Area	11.647	1.747	tons	Meisinger, 1991
Squash Harvested Area	6.588	0.988	tons	Meisinger, 1991
Sunflower seed, non-oil varieties Harvested Area	0.076	0.011	pounds	Meisinger, 1991
Sunflower seed, oil varieties Harvested Area	0.068	0.010	pounds	Meisinger, 1991
Sweet Corn Harvested Area	0.006	0.004	pounds	NRCS
Timothy seed Harvested Area	0.346	0.066	pounds	NRCS
Tobacco Harvested Area	0.039	0.002	pounds	NRCS
Tomatoes Harvested Area	4.353	0.653	tons	Meisinger, 1991
Triticale Harvested Area	1.765	0.200	bushels	NRCS
Vetch seed Harvested Area	0.346	0.041	pounds	NRCS
Watermelons Harvested Area	3.176	0.476	tons	Meisinger, 1991
Wheat for Grain Harvested Area	1.529	0.229	bushels	Meisinger, 1991
Wild hay Harvested Area	25.882	20.000	dry tons	NRCS

According to Alley and Vanlauwe (2009), the total nitrogen uptake is a function of the total crop biomass (top growth and roots) and it is calculated using:

Uptake (lb/acre) = yield * theoretical uptake (lb/bu)

5.3.2.2 Fraction of uptake per month

The fraction of the annual uptake mass is calculated on a monthly basis for each of the 12 growing regions using the recommended plant date. This does not account for the range of varieties used throughout the watershed. The curve information was informed by normalizing empirical data from peer-reviewed research to a fraction of the total uptake per month. The normalized data were averaged for each crop type where measurements were available. Uptake fraction per month was generalized to all the crop types modeled in Scenario Builder from the peer-reviewed research data on corn, soybeans, and winter wheat.

Improved methodology is being used for informing the curves. The timing of uptake should be based on the average temperature. Thus, heat units and the number of days warm enough to support crop growth, or growing degree days, were used to establish plant growth stages. The growing degree days are calculated as:

(Temperature Minimum + Temperature Maximum) / 2 – crop basal unit

The basal unit for corn is generally accepted as 50 degrees F. There are established basal units for most crops that are modeled in Scenario Builder. Since development is faster when temperatures are warmer, and slower when temperatures are cooler, then the use of growing degree days more closely informs the timing of nutrient uptake. Moreover, maturity dates for crops change by variety. In the Scenario Builder, we do not have various varieties of crops. The heat units serve to approximate the uptake for crops even without varietal differences being specified. Data using these methods is being prepared as of June 2009.

Application rate is determined by the uptake, so in essence the crop is spoon fed on a monthly basis.

Application rate (lb/ac) = total uptake (lb/ac)

This provides every crop acres with efficient timing of nutrients, which is a significant portion of nutrient management. However, application rates vary for nutrient management and non-nutrient management farms.

5.3.2.3 Nutrient Management Application Rate

Using the agricultural census, the nutrient management yield for each state is calculated differently:

> *Delaware*: average of the highest four of seven yields from the Agricultural Census. If less than seven Censuses are available, use as manure are available as long as there are greater than four.
>
> *Maryland*: average the highest 60% of the available Agricultural Censuses.
>
> *New York, Pennsylvania, District of Columbia, West Virginia, Tennessee, and North Carolina*: average the highest three of five yields from the Agricultural Censuses.

This is different from the non-nutrient management rate because the non-nutrient management target yield is the highest Agricultural Census yield instead of any recent average. The non-nutrient management yield cannot be greater than the upper limit (quantile p=0.95) of the Census to prevent exceedingly high yield goals that appear to be statistical outliers. The average application yield ratio (YR = nutrient management yield/upper limit yield) is 0.78. The rates are calculated as below by combining the application rate and uptake calculations:

Non-nutrient management application rate (lb/ac) = upper limit yield (bu/ac) * theoretical uptake (lb/bu)

Nutrient Management application rate (lb/ac) = nutrient management yield (bu/ac) * theoretical uptake (lb/bu)

The recommendations from each state's agronomy guide or nutrient management handbook were not complete for all of the crops modeled in Scenario Builder. Some generalizations were made among crops and geographic regions (Table 5-3).

Table 5-3: Nutrient application rate data generalizations

Growing Region	***Crop***	***Generalization, source of data***
DC 1	All crops	uses same values as MD
WV 1	All crops	uses same values as PA
NY 1	all hay with nutrients	Chenango County was used for calculations for nitrogen in grasses. Average yield was 75 T/A.
All regions	All seed crops	Used the theoretical maximum yield calculated from the census-reported yields and acres. For the years with missing data, used the average of the years with data. Delaware was missing all years so used MD data.
All regions	Aquatic plants	Used Maryland's published data
All regions	Bedding/garden plants	Used Maryland's published data
All regions	Bulbs, corms, rhizomes, and tubers,	Used Maryland's published data
All regions except DE	Canola	Used MD published information which correlated to http://www.ag.ndsu.edu/pubs/plantsci/crops/a1280.pdf
All regions	Cropland on which all crops failed or were abandoned	Set application rate to 50 lbs of N and P
All	Cut flowers	Used Maryland's published data

regions	and cut florist greens	
DE	fescue, orchard grass, and other field and forage	Used millet-sudangrass.
All regions	Foliage plants	Used Maryland's published data
All regions	Greenhouse vegetables	Used Maryland's published data
All regions	mushrooms	Spent mushroom substrate nutrient content from Penn state: http://spentmushroomsubstrate.turfgrass.psu.edu/links.cfm. Amount/acre assumes maximum amount is 10,000 lbs of spent mushroom substrate per acre, 2% N and 1% P per lb. Peter Shenderschoot, Penn State, personal communication, 1/9/2009
All regions	Nursery stock	Used Maryland's published data
All regions	Other nursery and greenhouse crops	Used Maryland's published data
All regions	Peanuts	Used Virginia's recommendations
All regions	Potted flowering plants	Used Maryland's published data
All regions	sod	Used Maryland's published data
NY 1, PA 1, PA 2, PA 3	Sunflower seed	used MD yields and NY app rates
MD 1, MD 2, MD 3, DC, NY, PA 1, PA 2, PA 3, WV	Tobacco	Advised by Dave Conrad, MD Tobacco Extension Specialist. Use Type 32, light air cured. Verified application rate in extension publications.
VA 1, DE	Tobacco	Used burley tobacco recommendations from Virginia
All regions but VA 1,	Turf grass (urban lawns)	100 lbs N/A, 50 lbs P/A based on ratio of difference from HGIC Master Gardeners and the Phase 4.3 rate for N. (For Virginia, used actual recommendation.)

VA 2, VA 3		
All regions	Vegetable and flower seeds	Used Maryland's published data
All regions	vegetables	MD vegetable values used where not available for other states.

There are several special cases for application rates. Pasture land uses used by the Watershed Model-HSPF include the following classifications: Nutrient Management Pasture, Pasture, and Trampled Riparian Pasture. This is to reflect the proclivity of cattle to spend more time in riparian areas. The implication is that more manure is directly deposited in these areas.

5.3.3 Nitrogen fixation

The Scenario Builder calculates the amount of nitrogen that is fixed by the plant on a monthly time-scale. Nitrogen fixation includes the portion fixed in the roots and taken up into the plant.

Legumes are a class of plants that generally grow pods. Legumes develop nodules on the roots that are a bacterial infection. These bacteria transform N_2 to NH_3, a process called nitrogen fixation. Thus, N is added to the plant-soil system from the air. The Scenario Builder reports the pounds/acre of ammonia (NH_3) that is fixed by crop, county, month, and year.

Leguminous plant types that are modeled are listed in Table 5-4. The Agricultural Census categories that include legumes but are not exclusively legumes are not considered for legume fixation. We do not calculate N fixation from these broader categories because the fraction of legumes is not known and can significantly vary at a plot scale (Table 5-5).

Each year is considered independent of all other years. Therefore, nutrients can not accumulate in the soil in data produced by the Scenario Builder. It follows that N in the soil after one year may repress N fixation. This situation is not considered in the calculation of these data.

No N is fixed in the month of planting. It was assumed that the nodules take 2-4 weeks to establish. For subsequent months of growth, the total amount of NH_3 is parsed evenly. That means that the same amount of N is fixed in the second month of growing as in the final month before the plant senesces. A perennial, like alfalfa, will fix the same amount every month between emergence (plant date for annuals) and first hard frost (harvest date for annuals).

It was assumed that fixation occurs on all leguminous plants, which would require that legumes are inoculated or sufficient rhizobia are present. It also assumes that carbon is at optimum levels for fixation to occur.

Nitrogen fixation amounts are generally not adjusted for temperature or rainfall in Scenario Builder or in the Chesapeake Bay Program's Watershed Model. The exception is alfalfa. The Watershed Model users can choose whether to calculate alfalfa fixation or use the alfalfa fixation provided from Scenario Builder. As of October 14, 2008, nitrogen fixation for alfalfa will be calculated by the Watershed Model so that rainfall and temperature data can parameterize fixation amounts.

The Chesapeake Bay Program's Watershed Model accounts for processes that occur after N fixation, such as where crops are killed and left on the soil or incorporated into the soil, thereby returning N to the soil. These data are not included in Scenario Builder.

Many researchers have indicated that fertilizer applications in the form of NO_3 do not decrease N fixation by legumes (Johnson et al., 1975; Blumenthal et al., 1996). These data refute the dogma that NO_3 substitutes for fixed N where NO_3 is increased. Literature searches did not produce data that quantifies the reciprocality of the NO_3 sorption and N_2 fixation. Without identifying values of N fixation and the interaction with NO_3 for each leguminous plant, we are unable to consider these data in the Scenario Builder model. Therefore, Scenario Builder calculates N fixation so that if there is adequate N available to the plant from nutrient applications, then N fixation is suppressed. The implication is that if a farmer applies fertilizer to legumes, then N is not fixed.

Additionally, this parameter is based on the assumption that 50% of what is fixed is taken up into the plant. The remaining 50% is returned to the soil in crop residue or is in the roots and is released into the soil over the coming seasons. This does not mean it is available; it may become immobilized in the organic fraction. The portion returned at senescence is the nitrogen credit considered in nutrient management plans (PA Agronomy Guide 2007-2008, Table 1.2-7 and the Mid-Atlantic NM Handbook, 2006 Table 4.4).

In New York, alfalfa is not persistent in years subsequent to planting. Within one to two years after planting, an alfalfa field typically only has 50% alfalfa. Yet, it is reported by the farmer to the Agricultural Census as an alfalfa crop. For this reason, New York N fixation by alfalfa was reduced by 50%.

The source of data for the soybean N fixation was based on a yield. For soybeans in Delaware, a yield of 30 lbs/acre was used. This was based on the average yield from Agricultural Census years between 1992 and 2002. For those states where fixation values were not reported for a crop, data was used from the nearest state that did report a value.

Table 5-4: Legumes for which N fixation is calculated.

NASS Crop Type	***CBP Land use***	***CBP Land use abbreviation***
Alfalfa hay	Alfalfa	Alf
Alfalfa seed	Alfalfa	Alf
Birdsfoot trefoil seed	hay-fertilized	HYW
Dry edible beans, excluding limas	Conventional or Conservation Tillage with Manure	HWM or LWM

Green Lima Beans	Conventional Tillage without Manure	HOM
Peanuts for nuts	Conventional or Conservation Tillage with Manure	HWM or LWM
Peas, Chinese (sugar and Snow)	Conventional Tillage without Manure	HOM
Peas, Green (excluding southern)	Conventional Tillage without Manure	HOM
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc.	Conventional Tillage without Manure	HOM
Red clover seed	hay-fertilized	HYW
Snap Beans	Conventional Tillage without Manure	HOM
Soybeans for beans	Conventional or Conservation Tillage with Manure	HWM or LWM
Vetch seed	hay-fertilized	HYW

Table 5-5: NASS categories that include legumes, but are not exclusively legumes

NASS Crop Type	*CBP Land use*	*CBP Land use abbreviation*
Other tame hay	hay-fertilized	HYW
Pastureland and rangeland other than cropland and woodland pastured	Pasture	PAS
Wild hay	hay-unfertilized	HYO

5.3.4 Erodible Area

Scenario Builder calculates the area of land available to be eroded. The area of bare soil is considered the amount available to be eroded. Therefore, we estimate the fraction of residue cover and canopy cover and assume the remainder is available for erosion. Residue and canopy cover are calculated using the Revised Universal Soil Loss Equation modeling tool (RUSLE 2 Version 1.26.6.4). It should be noted that residue and canopy cover do not directly correlate to the percentage of bare ground and that neither of these values used alone or the values used in combination are the same as the percentage of the ground covered. However, we were able to achieve realistic results in a consistent manner across the entire Chesapeake Bay Watershed.

The greater of the two variables, residue cover and canopy cover, were used on a monthly time scale. An underestimation may result in early plant growth period for low till crops because residue may still be on the ground and leaf cover may not overlap. This is not an issue for high till crops where most of the residue is plowed under at planting. This calculation is bound where the monthly value is greater than zero and less than 0.95. An alternative method of summing the residue and canopy cover was tested. This method provided less accurate results because canopy shades residue.

In general, the data are not representative of any individual site or situation. In addition, the data are not reflective of typical crop rotations used in the watershed. RUSLE 2 values should not be averaged. The planting dates used influence when the canopy cover numbers change. RUSLE 2 can show growth at any time of year, even if a crop will not grow at that time of year or in a given area. All data was generated without applying any other conservation practices or methods.

Variations in residue and canopy cover exist due to climatic variation, yields, tillage, and double cropping. How each of these variables was handled will be discussed in the following sections.

5.3.4.1 Spatial differentiation

The NRCS Crop Management Zones (CMZs) were used for generating spatial zones within the Bay region (Figure 5-2). The data in the CMZs are representative of typical planting dates and yields that are possible for a crop in the area. If more than one yield was available for a crop, a moderate yield was used. The information included in the CMZs is periodically updated and may vary from the information used in a different version. The templates used were those available in RUSLE 2 as of January 2009.

More than one Scenario Builder Growth Region may be represented by the same data set. Scenario Builder Growth Region MD 2 was divided into two areas—one east of the Bay and one west of the Bay. In the initial preparation of the dataset, the MD 2 East values were used for the entire MD 2 growing region. Quality control and assurance were performed in summer 2009 as the data were being more carefully prepared for use. These generalizations will be removed as part of that process. Kent and Queen Anne's County in Maryland use the same data as MD 1. CMZ 4.1 was used to generate the data for NY 1 and PA 1; CMZ 65.0 for Pa 2 and MD 3; CMZ 66.0 for MD 2 West and VA 2; CMZ 65.0 for MD 1 and PA 3; CMZ 62.0 for WV 1; CMZ 59.0 for MD 2 east and DE 1; CMZ 67.0 for VA 1; and CMZ 64.0 for VA 3.

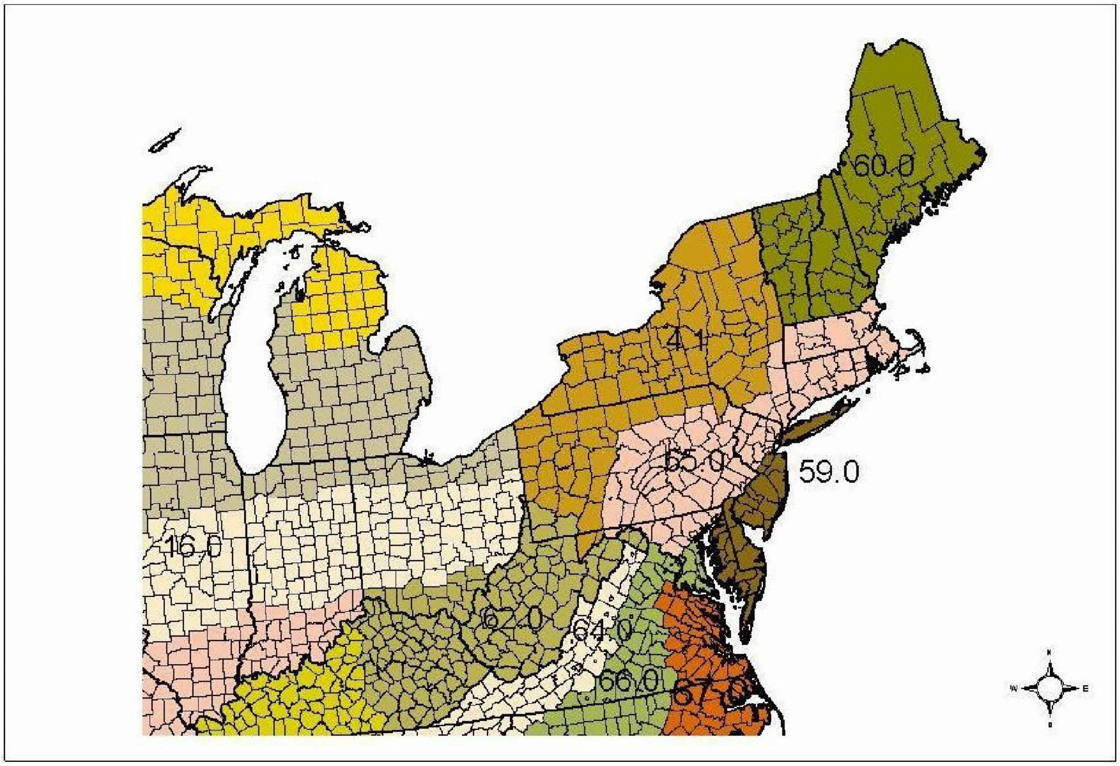

Figure 5-2: RUSLE 2 Crop Management Zones

5.3.4.2 Tillage

One of the most important variations in erodible land data is in the tillage practice. The Chesapeake Bay Program currently recognizes two different tillage practices: low till and high till. Low till is generally equated as conservation till and high till is generally equated with conventional till. NRCS Practice Standard 345 for Residue Management Mulch Till states, “The annual Soil Tillage Intensity Rating (STIR) value for all soil-disturbing activities shall be no more than 70 for high residue crops (e.g., grain corn) and no more than 10 for low residue crops (e.g., grain, soybeans). These STIR values will result in approximately 30% or more surface residue for the entire crop rotation.” By using the RUSLE 2 tillage management practices, the data necessarily meets the conservation tillage STIR values. Conventional establishment was usually represented by moldboard plowing and conservation tillage was usually represented by no-till planting methods as appropriate to the crop. The tillage method has minimal impact on the crop canopy but a major impact on the residue.

5.3.4.3 Continuous monoculture

The RUSLE 2 single year crop templates were used for annual crops and a non-establishment year was used for perennial crops. When using continuous monoculture, RUSLE 2 assumes a one-year rotation, where the same crop is grown with the same method year after year. This will potentially underestimate residue for fragile residue crops and overestimate residue for coarse residue crops. This is especially true in low till systems. In most places in the Chesapeake Bay Watershed, crops are not typically grown in a continuous fashion. Usually crops are grown as part of a rotation. This process of single crops is particularly limited for fruit and vegetables, which may have several crops in the same year. There are also differences in the timing and staggering of planting of fruit and vegetable production for direct sale versus processing purposes.

5.3.4.4 Data generalizations among crops

Where there were missing data for a particular crop in a particular growing region, values from the nearest growing region were used. The fruit and vegetable cover data was generalized among similar plants according to viney or bushy plant character. Turf grass (urban lawns) did not have a value generated from RUSLE 2 and 0.95 was used for the entire year. For cultivated summer fallow cropland and idle cropland, a consistent value of 0.05 was used. Failed crops were assigned a consistent value of 0.2. Many nursery crops that are grown out in the open used a consistent value of 0.5.

5.3.4.5 Pasture

Pasture cover data should be regarded with special care and considered as general guidance. Pastures vary greatly in management and grazing frequency and this variability is much greater than the management options in agronomic fields. The grazing variability particularly impacts canopy cover. Because of this management and impact variability, there are many limitations to using pasture cover values from RUSLE 2. RUSLE 2 is scheduled to be updated in late 2009 to better represent pastures. Other options for addressing pasture cover may involve summing the residue and canopy cover rather than selecting the greater of the two for any given date. This option may be explored for a later release of Scenario Builder.

5.3.4.6 Double cropping

Double cropping cover is addressed by classifying a double-cropped crop as its own crop type. Double crops are not currently given their own plant and harvest dates. This a known issue because it results in more total acres of the crops eligible for double cropping. This acreage is corrected in the Phase 5 Watershed Model - HSPF, but the application rates are increased as a result. Cover values for double cropping are the same as single crops. Variation will be addressed by differences in plant and harvest dates in the future.

5.3.5 Crop harvest yield-informed parameters

Yield data are selected from the NASS Agricultural Census for each crop modeled in Scenario Builder and the years 1982, 1987, 1992, 1997, 2002, 2007. Yield data are used to introduce variability due to geographical yield differences, such as those from soils.

6 BEST NUTRIENT MASS LOADING WITH TEMPORAL AND SPATIAL CHARACTER

Nitrogen and phosphorus are applied to crops, pasture, and turf in urban areas according to plant growth requirements. The plant growth requirements were established as application rates, discussed in Section 5.

Scenario Builder applies nutrients in a sequence, intended to mirror the applications in order of unavoidable, highest priority, and then least damaging from an economic point of view. The unavoidable nutrient application is the amount of manure that goes on pasture that is directly excreted from the animals. The highest priority applications are those that are high-value crops and would be a priority for a farmer. Lastly, manure may be applied simply as a way to dispose of excess. We assume that a farmer will do this application in such a way as to avoid harming crops. Nutrient over application could cause lodging in grains or other harmful effects on plants. This is least likely to occur on hay and pasture crops so application greater than plant need may occur where excess manure is produced.

The sequence of nutrient application is described in order in the following sections.

6.1 Manure Applied to Animal Production Areas

The sum of the manure that was removed due to storage loss is applied to land in the Watershed Model-HSPF land use classification as Animal Feeding Operation (AFO). These areas are considered the animal production areas. The lost manure is applied evenly across months and the data on the amount of manure from each animal type is kept distinct. Manure is applied to AFO in the county in which it was produced and 100% of the nutrients in lost manure are applied to the edge of stream load where no BMPs exist. Nutrients lost from an AFO acre are applied before the manure is land applied or transported. Some counties do not have AFO acres. This results in 100% of the manure produced going into storage and subsequently being spread to the land. AFO acres will be connected to animal numbers in the next version to prevent this from occurring.

6.2 Manure Applied through Direct Excretion

Manure is applied to pasture according to the amount of animals in a county and the amount of time that animal type spends in the pasture. These data are calculated on a monthly time scale for each county, keeping animal type distinct.

Even where there are animals in a county that typically would be pastured, if there are no pasture acres in that county, then there is no manure applied as direct excretion. Therefore, all of that animal type's manure will be stored and applied to cropland.

Manure applied via direct excretion is not considered as a component meeting the application rate. For example, if the application rate for a pasture were 25 lbs-N/acre and there were a herd of beef cattle pastured all the time on that land, then the amount of direct excretion on that land would not contribute toward meeting that 25 lb-N/acre rate. If a large herd were pastured much of the time a significant amount of manure would be directly excreted. On top of the direct excretion, the 25 lb-N/acre would also be applied.

Stored manure may augment the manure directly excreted on pasture, but direct excretion can only be applied to pasture and not other land uses. Livestock are sometimes foraged on harvested crop land. The Scenario Builder does not account for direct excretion of livestock on harvested crop land. The amount of time livestock are on this land is considered insignificant (Doug Goodlander, Pennsylvania, personal communication, 2008). Moreover, NASS data does not track this item and no source of data on the number of livestock or days livestock spend on these lands was available.

6.3 Starter Fertilizer Application

The starter fertilizer application amount is specified by crop type, county, and timing. Applications applied at the same time as planting generally were assumed to be starter fertilizer. Since it is unlikely that manure is applied at the same time that seeds are planted, starter fertilizer is always classified as inorganic fertilizer. Many crop types have split applications and other applications may be manure. Starter fertilizer is considered a portion of the total amount applied toward meeting the application rate.

6.4 Biosolids Application

Biosolids, or sewage sludge, is applied next in the sequence of nutrient applications. Note that the source of biosolids data is from each state in the watershed. As of July 2010, the only state that has provided biosolids data was Virginia.

Biosolids data is provided with the amount in an annual total. This annual amount is proportioned across the months based on the unmet amount in the application rate. A crop is eligible to receive biosolids if it is on a land use that is eligible to receive manure.

The crop type, nutrient type, and month are all kept distinct throughout this calculation. If there is remaining biosolids remaining after the application rate is met, then an error is logged with the amount of biosolids that could not be applied and reported to the user.

A modification to apportion the biosolids to various crops with a preference toward certain months that changes prior to 1997 was not implemented as of June 2009.

6.5 Manure Application

Manure follows next in the sequence of application. A crop may receive manure if it is a crop specified as a type that is eligible to have a manure application. Fruits and vegetables are among those that are not eligible to receive manure, for example. A crop is also eligible to receive manure if the application rate was not already met by direct excretion, starter, or biosolids. The amount of manure available to be applied is:

Manure produced – volatilization – storage loss – direct excretion = available manure

This manure is assumed to have been stored. Data are unavailable on the type and capacity of manure storage facilities throughout the Chesapeake Bay Watershed. Therefore, manure is available by an annual total. It is assumed that manure is applied only when the crop could utilize the nutrients. It follows that manure storage is available to handle the volume produced until applied. Manure is applied based on nutrient application rates and optimal crop use based on regional planting dates.

The annual amount of stored manure is proportioned across the months based on the unmet application rate amount. Manure is a limited nutrient, so it is applied in a priority order. The priority order is determined by crop sets. That is, crops are grouped into sets, and all crops in the first set receive manure nutrients prior to the subsequent set of crops. Where there is not enough manure to meet the application rate in any one set, then the manure is proportioned evenly among the crops in that crop set. This is calculated such that if crop A and crop B comprise crop set 1, and there is not enough manure to meet the full application rate of crops A and B, then whatever proportion of available manure is set to meet the same fraction of the application rate for crops A and B even though those application rates may differ.

Likewise, manure is proportioned over months where there is inadequate amount to meet the full application rate.

Crop, animal type, nutrient, and month are all kept distinct when tracking this data.

6.5.1 Transport of Manure in Excess of Application Rate

Manure is more likely to be applied in the county in which it was produced. Should excess manure be available after all application rates are met, manure is no longer eligible for *in model* transport. This transport function is not the same as, and is subsequent to, any manure transport reported by the Chesapeake Bay Program's regional partners as a best management practice.

Manure is transported only to another county if it shares a county border and is in the home state. Manure may not be transported across state lines in this function. Only counties that have excess manure after meeting the application rate are eligible for transport. The order in which counties transport within a state is based on the greatest amount of excess manure. Manure is transported to all adjacent counties proportionally based on adjacent counties remaining application mass need. That is, if an adjacent county does not have enough manure to meet its application rates, then manure will be transported to it. Transported manure is spread the same way stored manure is spread. If a county cannot transport all of its excess manure to adjacent counties, the remainder goes to disposal load in the home county.

6.5.2 Disposal of Manure beyond Meeting Crop Application Rate

Manure that exceeded the application rate in the county in which it was produced as well as any adjoining county is classified as disposal load. Disposal load manure is applied to crops at ten times the non-nutrient management application rate in a series based on the Watershed Model-HSPF land uses. The series is:

1. Non nutrient management pasture (PAS)
2. hay with nutrients (HYW)
3. non nutrient management row w/manure (HWM, LWM)

If there is still excess manure after applying to all of these crops on these land uses, then an error is logged with the amount of disposal load that could not be applied.

The amount applied is proportioned across the months equally. The monthly allocation for each crop in the land use(s) is applied based on the proportion of acres in the crop to the total acres of the crops in the land use(s).

6.6 Nitrogen or Phosphorus-Based Nutrient Plan

Manure nutrients may be applied on either an N or P-based nutrient management plan acres. Depending on whether an N or P-based plan is selected, then the opposite nutrient (P for an N-based plan) may be over or under applied depending on manure content of an animal type and crop application rate requirements.

Manure and biosolids are applied on an N-based plan for calibration of the Watershed Model-HSPF. The nitrogen application mass is compared to the plant available nitrogen applied. Phosphorus can be over or under applied. Remaining phosphorus need is only considered when applying fertilizer.

6.7 Inorganic Fertilizer Application

Inorganic fertilizer is applied last in the sequence of nutrient application. Where the application rate has not already been met with manure, then inorganic fertilizer is applied to meet the nutrient management application rate. It is not a limited nutrient and is never under or over-applied.

Chemical fertilizer is assumed to be mixed to specification. If N was met through manure, then chemical fertilizer containing only P may be applied. This is a more precise use of chemical fertilizers than may be typical in the Chesapeake Bay Watershed.

For urban lawns, or turf grass, the nutrients are only applied to the urban lawn areas that are in low intensity pervious urban and high intensity pervious urban land uses.

6.8 Comparison of Manure and Inorganic Fertilizer Application Amounts

6.8.1 Mineralization

A portion of manure N and P is mineralized. The portion of organic N and organic P mineralized during the first year is included in the calculation of plant available nutrients. The other portion of the manure, which includes organic N that is not mineralized, is applied to the land as well.

This means that an acre of corn with an application rate of 100 lb-N/acre will receive different masses of N depending on the nutrient source. If there are no animals in that county, then the corn acre will receive 100 lb of TN in the form of inorganic fertilizer. If there are all broilers in that county, then the corn acre will receive 148 lb of TN. The inorganic fertilizer composition is 75 lb NH_3 and 25 lb NO_3. The broiler manure is 0.26 lb NH_3/lb manure, 0.43 lb organic N/lb manure, 0.65 lb mineralized N/lb manure, and 0.0 lb NO_3/lb manure (Table 6-1). The nitrogen application rate is met through the nutrient forms of NH_3, mineralized N, and NO_3. The organic N is also applied, but not counted toward the application rate.

Table 6-1: Nutrient comparison of fertilizer and broiler manure

Nutrient	*Fertilizer*	*Broiler manure (lb-nutrient/lb-manure)*
NH_3	0.75	0.0026
Organic N	0	0.0043
Mineralized N	0	0.0065
NO_3	0.25	0

6.8.2 Crop Sets

The nutrients are applied to crops, which may be configured in sets; each set may have a member of one crop, or may be grouped so that many crops comprise one set. Sets can be configured so they are comparable to Watershed Model-HSPF land uses. Application of the nutrients within each nutrient type category (starter, biosolids, manure, and/or fertilizer) is proportional among the crops in each set where the nutrient is limited. Limited nutrients are biosolids and manure.

The crops are grouped so that each crop within a set receives nutrients as a group rather than sequentially within each set. The implication is that if there is only enough manure, for example, to meet the 20% of the nutrient application rate, then the other 80% will be met by fertilizer. Since this is done as sets, then each crop within the set each receives 20% of its nutrient application rate as manure and 80% as fertilizer rather than one set receiving primarily manure and the others receiving primarily fertilizer. The next set in the sequence would not have any manure available. The percent application is the same for crops within a set as well as for the months within that year.

6.9 Septic Systems

Septic systems are commonly designed so that the waste goes into a tank, where solids sink to the bottom, and liquids flow through to a septic field. While some phosphorus can become soluble, in this model, we assume that only nitrogen is distributed to the septic field.

To calculate the amount of nitrogen generated from septic systems, we used the number of people on septic systems in the Chesapeake Bay Watershed. This question was asked on the 1990 U.S. Census, but was removed in subsequent censuses. To estimate this number, we calculate the ratio of the number of people in a county on septic to the total number of people in the county from 1990. That ratio is multiplied by the total population in the county, interpolated from U.S. Census.

The calculation is on a county scale for each year:

> (No. of people on septic in 1990 / no. of people in 1990) * total population of year being calculated

Using the average household size and the number of septic systems on a land-river segmentation scale, we apply a value of 8.92 lbs-N / person / year and assume a 60% attenuation rate. This is calculated as:

> Total population on septic * 8.92 lbs-N / person * 0.40

7 APPORTIONING DATA TO THE WATERSHED MODEL - HSPF SEGMENTATION AND LAND USE CLASSIFICATIONS

The Scenario Builder model performs calculations at a county scale. Output may also be delivered at the Watershed Model-HSPF scale (Figure 7-1). Each model segment has up to 25 land uses. Data is narrowed to the Watershed Model-HSPF scale using an area weighted average. Methods for creating the land use data and apportioning it to the Watershed Model-HSPF scale are described in detail in the following sections.

Figure 7-1: Scale of Watershed Model-HSPF Phase 5 Output.

7.1 Using Land Cover Data to Create the Land Use Data

Land cover data are integrated and used to inform the area in each land use for each of the Watershed Model-HSPF's segments. These calculations are performed in the Chesapeake Bay Land Change Model (CBLCM) developed by Peter Claggett in 2008. The CBLCM forecasts the proportional future growth in urban land and resulting proportional loss of forests and agricultural for each Watershed Model segment. These segments are named land river segments, or lrsegs.

For each Watershed Model segment, the proportional increase in total urban area is distributed proportionally to the five urban land uses reported for the base year of the forecast. For example, a forecasted growth of 100 urban acres from 2002 to 2010 in LRseg *x* should be distributed to the five urban land use classes in LRseg *x* reported in the 2002 land use dataset used as part of the Phase 5.3 calibration. The resulting increase in total urban area is then subtracted proportionally from the total of all forest land uses (e.g., forests + harvested forests) and from the total of all agricultural land uses reported in the 2002 land use dataset for LRseg *x*.

All of the proportions of urban, forest, and agricultural land uses relative to the total urban, total forest, and total agricultural land uses are kept constant through time. However, an iterative mass balance routine must be implemented to maintain total land acres in each LRseg while preventing any one land use (e.g., hay with manure) from falling into negative acres. Negative land use acres must be redistributed to other related land uses. For example, if "hay with manure" is forecasted to fall below zero acres in year 2010 then "hay with manure" must be set to zero and the deficit acres subtracted proportionally from all remaining agricultural land uses. This correction must be run iteratively until all land uses contain zero or more acres. Note that Animal Feeding Operations, Extractive, Nursery, and Open Water were kept constant throughout the forecast period.

7.2 Determining the Agricultural Land Use Area

The agricultural land use area is taken directly from the National Agricultural Statistics Service's Agricultural Census. The data in Chapter 1 of these Censuses informs the area of agricultural land. The CBLCM informs urban area, and projects land use area into the future, but the Agricultural Census data on agricultural area is not altered for historical years in the CBLCM.

7.3 Assembling Land Use Data from Multiple Data Sets

Agricultural land use area is set from the Agricultural Censuses. The total segment area and water areas are never changed. Other land use areas may be changed to accommodate the segment area, agricultural areas, and water areas. This is done in a recursive procedure in a set order. Forest is found by subtraction from all other calculated areas.

7.4 Determining Crop Areas on Each Land Use

The Watershed Model-HSPF, Phase 5.3 uses 25 land use categories. Of these, 11 are aggregated crop types, three are pasture, and one is AFO. The pasture type, TRP, is equal to the amount acreage reported by the Bay jurisdictions in the Tributary Strategies. The regular pasture acres are then reduced according to the TRP acreage.

All calculations in the Scenario Builder are at the crop level. The Scenario Builder may accommodate infinite crop types. For the Watershed Model-HSPF Phase 5.3 calibration, most of the crops reported in the NASS Agricultural Census are used (exceptions include ginseng and dried herbs).

For data reported to the Watershed Model - HSPF, the crops are summed into Watershed Model land uses. The matrix of the crop or groups of crops in the Scenario Builder which make up each Watershed Model land category is in Table 7-1. The Watershed Model land uses have nutrient management and conservation versus conventional tillage analogues for most of the land categories in the matrix. The nutrient management and tillage analogues do not affect which crop is in each land use and are not reported separately in Table 7-1. The land uses that have nutrient management analogues include: alfalfa, row with manure, row without manure, hay with nutrients, and pasture. The land uses that have low-till (conservation) tillage analogues include: row with manure and nutrient management row with manure.

Table 7-1: Crops and the land use to which they are applied

Crop id	*Crop name*	*Major land use name*
178	Wheat for Grain Harvested Area	Row with manure
166	Triticale Harvested Area	Row with manure
141	Sorghum for Grain Harvested Area	Row with manure
143	Sorghum for silage or greenchop Area	Row with manure
145	Soybeans for beans Harvested Area	Row with manure
153	Sunflower seed, non-oil varieties Harvested Area	Row with manure
155	Sunflower seed, oil varieties Harvested Area	Row with manure

130	Rye for grain Harvested Area	Row with manure
112	Peanuts for nuts Harvested Area	Row with manure
119	Popcorn Harvested Area	Row with manure
94	Oats for grain Harvested Area	Row with manure
87	Mushrooms Area	Row with manure
88	Mushrooms Protected Area	Row with manure
10	Barley for grain Harvested Area	Row with manure
27	Canola Harvested Area	Row with manure
35	Corn for Grain Harvested Area	Row with manure
37	Corn for silage or greenchop Harvested Area	Row with manure
23	Buckwheat Harvested Area	Row with manure
50	Dry edible beans, excluding limas Harvested Area	Row with manure
54	Emmer and spelt Harvested Area	Row with manure
56	Escarole and Endive Harvested Area	Row without manure
52	Dry Onions Harvested Area	Row without manure
53	Eggplant Harvested Area	Row without manure
46	Cucumbers and Pickles Harvested Area	Row without manure
47	Cut Christmas Trees Production Area	Row without manure
48	Cut flowers and cut florist greens Area	Row without manure
25	Bulbs, corms, rhizomes, and tubers – dry Harvested Area	Row without manure
39	Cotton Harvested Area	Row without manure
29	Cantaloupe Harvested Area	Row without manure
30	Carrots Harvested Area	Row without manure
31	Cauliflower Harvested Area	Row without manure
32	Celery Harvested Area	Row without manure
33	Chinese Cabbage Harvested Area	Row without manure
34	Collards Harvested Area	Row without manure
14	Beets Harvested Area	Row without manure
15	Berries- all Harvested Area	Row without manure
19	Broccoli Harvested Area	Row without manure
12	Bedding/garden plants Area	Row without manure
9	Asparagus Harvested Area	Row without manure
7	Aquatic plants Area	Row without manure
107	Other nursery and greenhouse crops Area	Row without manure
22	Brussels Sprouts Harvested Area	Row without manure
109	Parsley Harvested Area	Row without manure
89	Mustard Greens Harvested Area	Row without manure
90	Nursery stock Area	Row without manure

96	Okra Area	Row without manure
84	Land in Orchards Area	Row without manure
86	Lettuce, All Harvested Area	Row without manure
78	Head Cabbage Harvested Area	Row without manure
79	Herbs, Fresh Cut Harvested Area	Row without manure
80	Honeydew Melons Harvested Area	Row without manure
81	Kale Harvested Area	Row without manure
64	Foliage plants Area	Row without manure
68	Garlic Harvested Area	Row without manure
69	Green Lima Beans Harvested Area	Row without manure
70	Green Onions Harvested Area	Row without manure
121	Potatoes Harvested Area	Row without manure
123	Potted flowering plants Area	Row without manure
114	Peas, Chinese (sugar and Snow) Harvested Area	Row without manure
115	Peas, Green (excluding southern) Harvested Area	Row without manure
116	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	Row without manure
117	Peppers, Bell Harvested Area	Row without manure
118	Peppers, Chile (all peppers – excluding bell) Harvested Area	Row without manure
134	short-rotation woody crops Harvest Area	Row without manure
135	short-rotation woody crops Production Area	Row without manure
125	Pumpkins Harvested Area	Row without manure
126	Radishes Harvested Area	Row without manure
157	Sweet Corn Harvested Area	Row without manure
158	Sweet potatoes Harvested Area	Row without manure
147	Spinach Harvested Area	Row without manure
148	Squash Harvested Area	Row without manure
168	Turnip Greens Harvested Area	Row without manure
169	Turnips Harvested Area	Row without manure
170	Vegetable & flower seeds Area	Row without manure
138	Snap Beans Harvested Area	Row without manure
139	Sod harvested Area	Row without manure
162	tobacco Harvested Area	Row without manure
164	Tomatoes Harvested Area	Row without manure
173	Vegetables, Mixed Area	Row without manure
174	Vegetables, Other Harvested Area	Row without manure
129	Rhubarb Harvested Area	Row without manure
177	Watermelons Harvested Area	Row without manure

175	Vetch seed Harvested Area	Hay with nutrients
160	Timothy seed Harvested Area	Hay with nutrients
127	Red clover seed Harvested Area	Hay with nutrients
136	Small grain hay Harvested Area	Hay with nutrients
132	Ryegrass seed Harvested Area	Hay with nutrients
97	Orchardgrass seed Harvested Area	Hay with nutrients
101	Other field and grass seed crops Harvested Area	Hay with nutrients
103	Other haylage, grass silage, and greenchop Harvested Area	Hay with nutrients
105	Other managed hay Harvested Area	Hay with nutrients
20	Bromegrass seed Harvested Area	Hay with nutrients
17	Birdsfoot trefoil seed Harvested Area	Hay with nutrients
44	Cropland on which all crops failed or were abandoned Area	Hay with nutrients
58	Fescue Seed Harvested Area	Hay with nutrients
41	Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area	Hay without nutrients
42	Cropland in cultivated summer fallow Area	Hay without nutrients
180	Wild hay Harvested Area	Hay without nutrients
111	Pastureland and rangeland other than cropland and woodland pastured Area	Pasture
45	Cropland used only for pasture or grazing Area	Pasture
26	Bulbs, corms, rhizomes, and tubers – dry Protected Area	Nursery
49	Cut flowers and cut florist greens Protected Area	Nursery
8	Aquatic plants Protected Area	Nursery
13	Bedding/garden plants Protected Area	Nursery
108	Other nursery and greenhouse crops Protected Area	Nursery
91	Nursery stock Protected Area	Nursery
71	Greenhouse vegetables Area	Nursery
72	Greenhouse vegetables Protected Area	Nursery
65	Foliage plants Protected Area	Nursery
124	Potted flowering plants Protected Area	Nursery
140	Sod harvested Protected Area	Nursery
171	Vegetable & flower seeds Protected Area	Nursery
76	Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	Alfalfa
1	Alfalfa Hay Harvested Area	Alfalfa
3	Alfalfa seed Harvested Area	Alfalfa

0	Turf grass	Urban

Some over-arching guidelines governed the calculations. Where inconsistencies or error introduced in the estimation of withheld ("D") data led to inconsistencies between crop areas and land areas, then the land areas were adjusted to be commiserate with the crop areas.

Maryland currently has a commodity cover crop program that allows a partial payment for crops planted but not harvested when no nutrients are applied in the fall. If the farmer applies spring nutrients and harvests the crop for sale, then there is a smaller subsidy payment (R. Wieland, personal communication, 2008). This may provide some overlap in NASS data for small grains and cover crops reported as a best management practice.

Vegetables that are grown in plasticulture are not treated differently in this model. Plasticulture managed vegetables are grown so that approximately one third of a field is covered (Ed Joiner, Nutrient Management Planner, VA, personal communication 2008). This increases infiltration since the irrigation system is under the plastic and decreases erosion. It also decreases volatilization. If plasticulture is about 7,000 acres in Virginia, and there are 195,000 acres in high-till row crop without manure (HOM), then these acres comprise 3.6% of the total and the plastic-covered portion of the field is 1.1% of that land use. Therefore, this is assumed to be insignificant portion for the outcome of loads.

Sunflower can be for seed oil or for wildlife. Where sunflower is grown for wildlife stands then it is not double cropped but left fallow other times of the year. NASS reports sunflowers in two categories: Sunflower seed, non-oil varieties and Sunflower seed, oil varieties. Only sunflower seed, oil variety is available to be double cropped. Years prior to 2002 do not have sunflower seed split into the two categories, so double cropping is not calculated for sunflowers prior to the categorization split. Rather, sunflower-all are categorized as sunflower non-oil varieties for the years prior to 2002.

Barley can be grown for grain or silage, yet the agricultural census does not differentiate. Barley for silage is lumped with the category haylage, grass silage, or greenchop whereas Corn and Sorghum silage and greenchop are distinct. Where grown for silage it is harvested 1.5 months earlier and is double-cropped with either sorghum or corn. This is common in the dairy industry (Bobby Long, Nutrient Management Planner, VA, personal communication 2008). Since the source data do not allow barley for silage as a distinct category, barley effectively will only be double cropped as a grain with sorghum.

While potatoes grown in the southern portion of the Chesapeake Bay Watershed are harvested early enough that they may be double cropped with beans and wheat, they are not included as a crop that may be double cropped with anything other than vegetables (Ed Joiner, Nutrient Management Planner, VA, personal communication 2008). Vegetables are double cropped. This is to be handled by a not-yet-implemented feature to Scenario Builder for multiple plant and harvest dates within each crop type or land use.

7.5 Determining when two crops are planted on the same acre in the same 12-month period

When a farmer plants a summer crop followed by a winter crop, then two different crops may exist on the same acre of land. This situation is termed double-cropping. Double cropping is accounted for in Scenario Builder by determining the amount of land available to be double-cropped and subtracting the actual acres of crop types that are eligible to be double-cropped. This requires identifying pairs of crop types that are typically cropped one after the other.

Table 7-2 List of crops eligible for double cropping.

Major Landuse	*Crop Name*	*First crop?*	*Second crop?*
Row with manure	Barley for grain Harvested Area	-	Yes
Row with manure	Buckwheat Harvested Area	-	Yes
Row with manure	Canola Harvested Area	Yes	-
Row with manure	Corn for Grain Harvested Area	Yes	-
Row with manure	Corn for silage or greenchop Harvested Area	Yes	-
Row with manure	Dry edible beans, excluding limas Harvested Area	-	Yes
Row with manure	Emmer and spelt Harvested Area	-	Yes
Row with manure	Oats for grain Harvested Area	Yes	-
Row with manure	Popcorn Harvested Area	Yes	-
Row with manure	Rye for grain Harvested Area	-	Yes
Row with manure	Sorghum for Grain Harvested Area	Yes	-
Row with manure	Sorghum for silage or greenchop Area	Yes	-
Row with manure	Soybeans for beans Harvested Area	-	Yes
Row with manure	Sunflower seed, oil varieties Harvested Area	Yes	-
Row with manure	Triticale Harvested Area	-	Yes
Row with manure	Wheat for Grain Harvested Area	-	Yes

To determine the area for double cropping, the total harvested area (single line item in Ag census) is reduced by the area of ineligible crops. If the result is negative, there are no double crops. Positive acreage is compared to the sum of area for all crops above (double croppable). If double crop acreage is less than total harvested minus double crop ineligible, then no double crops exist. If the double crop area exceeds the harvested area, the difference is the acreage of double crops. Proportions of this acreage from each first crop set and each second crop set are based on acreage from each crop to the total.

> For example, if corn is 50%, sunflower seed-oil is 2%, and sorghum is 48% of land acreage as reported in the agricultural census, then the number of acres double-cropped will be covered by 50% corn, 2% sunflower seed-oil, and 48% sorghum (This example assumes there are enough acres of the first crop to accommodate all acres of the second double-croppable crop).

Finally, the acres are marked as double cropped to have independent plant and harvest dates. If the acres of the second crops or first crops are imbalanced, the remainder is single cropped and the harvested area is adjusted.

> For example, if first crops are 300 acres and second crops are 50 acres and total harvested area is 100 acres, the total harvest acreage is increased to 300 acres where 50 are double cropped. This can be done to accommodate second crops too.

At this point, we have the acres of crops on model land uses including double cropped acres.

7.6 Determining urban lawn areas

The area of the crop type "turf grass" is found by multiplying the fraction of urban lawn by each of the urban categories: low intensity pervious urban and high intensity pervious urban for each county and year. The fraction of urban lawn was determined by subtracting the acres of forested urban land from the total acres of pervious urban land within each county. The remaining pervious urban land is assumed to be turf grass. Many older subdivisions appear forested from a land cover perspective. The Watershed Model-HSPF Phase 5.3 land cover, however, uses housing unit and residential road density to identify such areas. To differentiate urban forests from lawns under canopy, the larger interior forest patches were used - eliminating edge and speckled forest areas. The GIS methods were as follows:

1) Create an urban mask using the Phase 5.3 land cover dataset
2) Within the urban mask, separate and group all forests and wetlands
3) Map interior forests by shrinking the forest/wetland extent around the edges by 1 cell (98.4 ft.).
4) Eliminate all patches of interior forest less than one-acre.
5) Expand remaining interior forest patches back to their original extent.
6) Summarize the acres of interior urban forest for each county.
7) Summarize the total urban extent (land cover, not land use).
8) Using a 2001 P5.3 land use file (corresponding to the date of the imagery), estimate the total urban and pervious urban land use acres by county. Pervious urban acres include "construction".
9) Calculate a land cover to land use adjustment factor based on the ratio of total urban land cover to total urban land use per county.
10) Multiply the adjustment factor by the total acres of interior urban forest per county and subtract that from the total pervious urban land use acres to derive acres of turf grass.

On average, turf grass equals 79% of the urban area in each county and 93% of what we call either high or low intensity pervious urban. Cappiella and Brown (2001) measured the percentage of open space on residential lots to range from 68% to 90%. Robbins et al., (2003) calculated the maximum potential lawn area in 205 residential census tracts in Ohio as averaging 82%. These estimates are liberal in that they do not subtract non-lawn areas (forests, flower beds, etc.) from their open space percentages. However, the numbers due lend some support to our county average of 79% (44% min and 97% max) (P. Claggett, personal communication, 2009).

The nutrients are only applied to the urban lawn areas that are in low intensity pervious urban and high intensity pervious urban land uses, although the turf grass area available was calculated using construction.

7.7 Deriving the Area for Agricultural Production

Animal production areas are generally those areas located around barns and where manure storage is most likely to occur. The Chesapeake Bay Program names these areas AFOs. These areas are where manure lost during storage and handling loss is applied. AFO land areas are added to existing agricultural land use areas using the following criteria.

1. For each county and year, multiply the number of farms for each animal type times the appropriate value found in Table 7-3.
2. AFO acres are added to the agricultural acres.
3. AFOs are broken down into land segments, and later into land-river segments, using an area weighted average based on the amount of agriculture in the county. The acres of AFOs in the county are multiplied by the agricultural acres in each land-river segment and divided by the total agricultural acres in the county. Agricultural acres are defined as those in the land uses:
    - animal feeding operations
    - alfalfa
    - row without manure
    - row with manure
    - hay without nutrients
    - hay with nutrients
    - pasture
    - degraded riparian pasture
    - nursery

Table 7-3: Animal Feeding Operation Acres/Farm by Animal Type

Item Name	*Acreage/farm*
Cattle and calves	0.5
Total hogs and Pigs	0.2
Any Poultry	0.25

Sheep and Lambs	0.1
Milk goats	0.05
Angora goats	0.05

The Agricultural Census only lists farms by animal type, yet many farms have more than one animal type. Certain acreages are designated for each farm with an animal type; therefore areas that are shared by more than one species of animal are overestimated.

The land area of the farm is not related to the AFO size, but rather the size of an animal type and the number of animals.

On AFO land, the following animal types are not captured: Other poultry (such as ducks, geese, emus, ostriches and squab) or miscellaneous livestock and animal specialties (such as bison, llamas, and rabbits). We assume that there are few farms with significant acreage specializing in solely these animals, so that land area is captured under other animal types.

7.8 Disaggregating Data from County to Watershed Model-HSPF Segments

County data is parsed to the Watershed Model-HSPF land-river segments by computing the ratio of agricultural acres in the land-river segment to the amount of agricultural acres in the county and multiplying that ratio by the crop acres in the county. Checks are put in place to make sure the sum of land area in the land-river segments that make up a county match the total for the county. The same procedure is used for animal numbers.

8 BEST MANAGEMENT PRACTICE IMPLEMENTATION

8.1 Introduction to Phase 5 BMPs

The effectiveness estimates for best management practices (BMPs) that are implemented and reported by the Chesapeake Bay partners, as well as those planned for future implementation, were reviewed and refined for the Phase 5 Model (Simpson and Weammert 2008). The objective was to develop BMP definitions and effectiveness estimates that represent the average operational condition of the entire watershed. In the previous versions of the Watershed Model, relatively optimistic effectiveness estimates were assigned that were often based on controlled research studies that were highly managed and maintained by BMP experts. This approach failed to take into account the variability of effectiveness estimates in real-world conditions where farmers, county stormwater officials, and others who are not BMP scientists, are implementing and maintaining BMPs across wide spatial and temporal scales with various hydrologic flow regimes, soil conditions, climates, management intensities, vegetation, and BMP designs. By assigning effectiveness estimates that are more closely aligned with operational, average conditions, the Phase 5 Model and any derivative watershed plans will better represent watershed monitoring observations.

BMP design objectives typically aim to meet three criteria of: 1) minimizing offsite nutrient and sediment impacts, 2) maintaining a healthy productive soil base, and 3) meeting landowner/producer objectives. An array of nonpoint source conservation practices is available to address nutrient and sediment pollution problems. Soil, weather, slope, cropping system, tillage method, and management objectives influence the set of practices used to reduce nutrient and sediment export and protect soil quality. The practices installed are the result of an on-site evaluation by a technical specialist. Site conditions, production system, crop rotation, owner/producer objectives, and other factors need to be taken into account when developing a conservation plan which is usually the first step in BMP installation.

Conservation practices, or BMPs, may take many forms, but essentially can be placed into one of four categories: prevention, land conversion, in-field protection, and reduced rate of load increase (Table 8-1).

The CBP applies an adaptive management approach to BMP development that allows for forward progress in BMP implementation, management, and policy, while acknowledging uncertainty and knowledge limitations. The adaptive management approach to BMP development incorporates the best applicable science along with best current professional judgment into current effectiveness estimates while acknowledging that going forward the best available knowledge will improve and change.

Table 8-1: Types of conservation practices/BMPs.

Category	Definition	Result/Example
Application Reduction	Creating or using less nutrients for land application.	Reduces nutrient production (Ex: precision feeding, feed additives) - or - Reduces rate of nutrients applied (Ex: nutrient management plan)
Land use Change	Land is converted from one type of use to another with a different intensity.	Land restoration or enhancement (Ex; wetlands) - or - Land taken out of intensive agricultural use (Ex: CRP, CREP)
Efficiency change	Agronomic changes affecting the amount of nutrient lost from land	Conservation plans decrease loss -or- Bypassed filter structures result in increased loss
Load Reduction	The amount of nutrient	Erosion control structures prevent

	entering water bodies is changed.	movement of sediment and nutrients to surface water. Often reduction are calculated per BMP foot.
Systems change	Existing infrastructure that has been converted to a different system	Septic connections result in fewer septic systems and become point sources.

There are other types of BMP that are applied within or adjacent to the estuary. These estuarine BMPs include, SAV plantings, offshore structures to reduce wave action, and oyster bar protection or creation among others. These tidal Bay BMPs are outside the Phase 5 model domain, which stops at the tidal water's edge, but to provide a complete accounting of all management practices used by the Chesapeake Bay Program, these estuarine BMPs are described in Section 6.8.

8.2 Methods Used to Determine BMP Effectiveness

8.2.1 Factors Considered in the Effectiveness Estimation

The estimation of BMP efficiencies under operational conditions was guided by one key question: Is BMP efficiency recommended by the experts and/or from literature representative of what would be expected at the watershed scale? If the efficiency does not represent watershed-wide effectiveness, an adjustment was made to reflect the operational conditions of the watershed. When no quantified data on how much to adjust research values to reflect operational values exists, best professional judgment was exercised based on known scientific processes to make an adjustment on the efficiency.

The BMP efficiencies were estimated primarily through literature review and professional judgment. Literature on individual BMPs was reviewed and their definitions were recommended by selected experts (Simpson and Weammert 2008). Specifically, these experts were asked to review literature that is applicable to the Chesapeake Bay watershed, with the applicable location defined as humid, temperate climates east of the Rockies. Experts were also asked to provide efficiency recommendations that should be used in the Chesapeake Bay Program's Watershed Model and associated Tributary Strategies from literature values. The expert recommendations were augmented by the application of the following criteria:

- Efficiency recommendations should reflect operational conditions, defined as the average watershed-wide condition. Research scale efficiencies were adjusted to account for differences upon scaling up to the watershed scale.
- Studies with negative efficiencies, i.e., the BMP acted as a source, not a sink for nutrient and/or sediment were included in the efficiency development process as they reflected real world operational conditions.
- The evaluation criteria and process should be consistent among all experts involved.
- Peer reviewed literature has been subject to stringent evaluation, and results from that literature were given more weight than literature without the same review process.

- Data from individual BMP project sites were utilized over median or average values calculated from multi-site analysis.

The expected spatial and temporal variability for a practice was estimated based on available science and knowledge of the expected geographic extent for implementation of the practice. Different reduction efficiencies were established for practice implementation across different physiographic, geomorphic, and hydrologic settings. Where possible, efficiencies were adjusted for surface water and groundwater interactions (permeability), along with geology and soil types (slope, seeps, floodplain, etc.). BMPs such as cover cropping are affected by age, size, time to maturity, species composition and site specific conditions, creating spatial and temporal variability in efficiencies.

Management conditions, including BMP operation and maintenance, design and construction supervision, and/or land use change will also impact efficiencies, usually making them lower than at research scales. While there is little quantitative information on how BMP efficiencies should be adjusted to account for the impacts of improper maintenance on receiving waters, general adverse impacts of poor construction or maintenance are understood to occur. If maintenance is neglected a BMP may become impaired, and will no longer provide its designed functions. Proper maintenance of outlet structures, flow splitters, and clean out gates is critical to achieving a stormwater BMP's designed efficiency (Koon, 1995). "Average" management was assumed but it was assumed the practices were implemented and being operated and maintained. Reviews and audits of BMP implementation and performance are needed to better estimate the actual impacts of reported practices.

8.2.2 Translating Research Studies to Operational Scale Efficiencies

Using research-site and demonstration-site derived efficiencies for watershed scale implementation efforts will fail to reflect the spatial variability of the entire watershed. Both the scale and management differences between a research plot and a BMP site will alter efficiencies. The research-based estimates of best management practices need to be adjusted to provide more realistic estimates of efficiencies for widespread adoption of the practice.

Virtually all research data is generated under controlled management conditions; meaning that studies are done on typical or representative soils (marginal land is usually excluded), agronomic management is optimal (timely planting, precise farm management, high seed emergence, etc.), and other hazards (goose grazing, deer grazing, etc) are minimized or excluded. Hence, the research estimates are more representative of a best-case scenario. This optimistic scenario needs to be adjusted to lower effectiveness when the efficiencies are being applied to widespread field implementation under "average conditions" across the Chesapeake Bay watershed.

Given the multitude of factors that influence water quality at the watershed scale of analysis, detecting a change does not lead to the conclusion that the BMPs were responsible for the change unless the other factors can be ruled out. This problem becomes more severe as watershed size increases. For these reasons the scale of the study was taken into account and reflected in efficiency adjustment as research and demonstration site derived efficiencies for watershed scale implementation fail to reflect the spatial viability of the entire watershed. Data extrapolation to any scale is difficult, but research, field, and watershed scale estimated efficiencies will differ for the same BMP which justifies adjusting efficiencies when comparing BMP efficiencies between scales.

8.2.3 Using Best Professional Judgment

While literature was reviewed and experts were recruited to suggest BMP efficiencies for annual practices in the BMP project, there were several cases where it was necessary to use best professional judgment to adjust for spatial, temporal, and management variability and the estimated resulting change in practice effectiveness at widespread "average" implementation across the Chesapeake Bay watershed (Simpson and Weammert 2008). On some occasions it was necessary to adjust for differences in approach among the experts.

We chose to consider the need for efficiency modification based on best professional judgment on a practice-by-practice basis based on availability of literature, field scale implementation data, recent revisions to BMP efficiencies, and other factors. This resulted in a variable application of best professional judgment to different practices which was warranted based the factors above (Simpson and Weammert 2008).

It must also be recognized that these BMP efficiencies are being developed using an adaptive management approach that recognizes that our knowledge is incomplete. Adaptive management proposes a science based and conservative approach to efficiencies. This allows BMP efficiency review and updating at recurring intervals based on new research, monitoring, and experience. The conservative approach is always advisable in adaptive management and is particularly warranted here since there is little if any data that suggests actual watershed-wide implementation efficiencies as high as those in the research literature.

8.2.4 Accounting for Variability in Management

When scaling-up BMPs from the research plot or small scales to watershed-wide implementation it's important to account for the impact that expanded variability will have on practice performance. Several studies have shown that when BMPs are applied across even a small watershed the resulting improvement in water quality is far less than would have been projected based on research scale data. While some part of this may be due to "legacy" nutrients or sediments, this does not explain all of the difference. USGS research has suggested an average nitrogen lag time of about ten years in the Bay watershed to see the full impact of BMP changes.

Spatial and temporal variability due to soils, hydrology, geology, climate, etc. are often recognized as sources of variability. However, management and operation can also be highly variable between research watershed scales, operational watershed scales and even between different managers within an operational watershed scale. When practices are implemented across a large area on parcels managed by many different individuals, it is important to assume an "average" level of expertise, control and management in planning design, implementation and operation of any given BMP. While there may be limited data quantifying the difference between research and "average" planning, design, implementation and management, it is recognized that widespread implementation rarely has the same level of oversight and control that is essential to get statistically meaningful results observed at research scale. As a result, there is a need to lower effectiveness from the research scale when widespread implementation occurs.

While the effect of "average" management has been considered in proposed BMP efficiencies, whether or not a practice is fully or partially implemented and whether it is properly maintained and revised, replaced, or upgraded as needed was not considered in these BMP Effectiveness estimates. These tend to be program management and compliance issues and should be addressed in considering the actual likely impact of implementation of a suite of BMPs as part of a watershed management plan, however, they were not considered in development of efficiencies for individual BMPs. We assumed the BMPs were implemented and revised, upgraded, or replaced as recommended for the practice.

8.2.5 Incorporating Negative Efficiencies

Negative BMP efficiencies are reported in literature, usually due to natural processes, or issues associated with constructing and operating a BMP. Those negative efficiencies were included in the analysis, because in some situations BMPs act as a source rather than a sink (Simpson and Weammert 2008). Errors in the design, construction, and maintenance of a BMP can also create a system that is unable to provide its expected pollutant removal. In some cases, these errors can lead to flow bypassing the whole BMP, possibly resulting in negative efficiencies. Additionally, BMPs with permanent water pools often release phosphorous from saturated sediment, which can leach phosphorous into the water column, causing negative efficiencies.

8.2.6 Literature Used to Determine BMP Effectiveness Estimates

The literature cited in efficiency estimation was screened based on pre-established criteria. For existing BMP efficiencies that were developed with limited data or best professional judgment, newly available literature was consulted before refinement. Applicability and credibility of new studies were vigorously reviewed. Alternatively, BMP efficiencies that were developed from sufficient/adequate data, a large body of consistent data was required to justify a refinement to the BMP efficiency. Among consulted literature, peer reviewed literature was given more weight than design standards and manuals. Peer reviewed literature has undergone a robust, critical screening before it is published; while non-peer reviewed literature is not submitted to the same screening process. Design manuals are written to result in aspirational BMP effectiveness, and often include additional components that increase the BMPs estimated median effectiveness. As such, more confidence lies in the peer reviewed literature.

To respond to CBP workgroup concerns about the literature and data used, a task group within STAC was requested to review and assess the process whereby the University of Maryland/Mid-Atlantic Water Program arrived at BMP effectiveness estimate recommendations. Specifically, they were requested to review the logic, approach and process used to develop BMP definitions and efficiencies. The STAC report concluded:

"The Chesapeake Bay model must be calibrated to function with operational rather than research BMP efficiencies. Hence, if reported negative efficiencies reflect operational conditions, they should be considered in an assessment of the BMP efficiency literature. Peer-reviewed literature has more credibility than do design standards/manuals which have not been subjected to independent examination."

Peer reviewed literature was also categorized based on scope of research. Studies taking place on a single site with a single BMP more accurately represented the BMP efficiency compared to single site studies with multiple BMPs and the two previous study types were preferable to multi-site studies. Multi-site review and analysis studies generally lost the specificity of individual site characteristics. Characteristics of a site like soils, climate and hydrology are important in evaluating the effectiveness of a BMP. Also, multi-site review and analysis studies generate a median or average of one BMP or multiple BMPs which can enhance or diminish the value of the effectiveness estimate. Furthermore, multi-site studies tend to underreport or not publish negative efficiencies.

It is important to note that none of the above criteria takes into account the variability and uncertainty associated with rate of implementation, operation and maintenance, replacement, spatial variability or tracking and reporting of a BMP. These factors that adjust efficiencies need to be investigated and applied to future efficiency refinement procedures.

Developing efficiencies that reflect operational, real-world conditions requires a holistic view point. There are certain qualities of research studies that do not incorporate all the factors that will influence operational efficiencies. To account for this, research based effectiveness estimates must be adjusted using the aforementioned guidelines.

Model output and monitoring data must be consistent and used appropriately. Better research on demonstration and monitoring of BMP, system and small watershed conservation effects will increase confidence in BMP effectiveness. Finally, managers, policymakers, and involved citizens must be made aware of potential implications of the iterative-adaptive BMP effectiveness approach so they understand the recurring need to change effectiveness estimates as knowledge advances (Simpson and Weammert, 2007).

8.2.7 Oversight and Review

As BMP efficiencies were reviewed and recommended by multiple experts, naturally there were differences in their approaches to efficiency development and adjustment. Additional overview and adjustment were exercised to ensure consistency of BMP evaluations among all parties involved (Simpson and Weammert 2008).

CBP workgroups with expertise on specific BMPs reviewed the BMP reports. They first determined if tracking and reporting data on BMP implementation was available in each jurisdiction to receive credit in the Watershed Model for the BMPs associated nutrient and sediment reductions. Some BMPs are subcategorized based on certain design elements. If a jurisdiction did not have existing infrastructure in place to report at sub-categorical level, either the jurisdictional program managers refined reporting procedures to reflect this new detail or a default definition and effectiveness estimate were substituted.

The report was further reviewed to ensure all pollution reduction mechanisms associated with a BMP were captured by the definition and effectiveness estimate. Applicable NRCS practice codes were added to the BMP definitions to assist with tracking and reporting. While the source area workgroups reviewed and modified the practice reports, the Tributary Strategy Workgroup (TSWG) analyzed the reports for their modeling components. How the practices are modeled (i.e., BMP category) needed to be agreed upon. After the TSWG and source area workgroups approved the BMP definitions and effectiveness estimates, the Nutrient Subcommittee (NSC), along with UMD/MAWP conducted a ranking exercise across all the BMPs. This process was used to evaluate the logic and consistency of all the BMP effectiveness estimates. Following NSC approval of the BMP reports, the Water Quality Steering Committee approved the BMP definitions and effectiveness estimates for use in Bay policy and modeling.

8.3 BMP Types

The five types of BMPs: Land use change, application reduction, efficiency, load reduction and systems change are discussed in detail.

8.3.1 Land Use Changes Due to BMP Implementation

The base scenario-year land uses are modified according to the information on BMP implementation supplied by individual State agencies. Nutrient and/or sediment load reductions resulting from land use changes due to BMPs implementation are simulated in the Watershed Model, such as the case when higher-yielding land uses such as *conventional tillage with manure* are converted to the ones exporting lower levels of pollutants such as *conservation tillage with manure*.

8.3.2 BMP Efficiency Estimates

In the Phase 5 Model the BMP reduction efficiencies are applied, across the entire Bay watershed. In the model, the simulation of a particular land use within a land-segment is not a representation of all the different types of that particular land use in the segment. The land use is modeled as a single representative average land use, therefore, the assumption of a representative nutrient and sediment reduction capacity is reasonable. Section 8.4-8.6 lists the BMPs in the model associated with reduction efficiencies and efficiencies for total nitrogen, total phosphorus, and sediment. The appendix to the table in this section shows reductions specific to certain geographies that have inherently different efficiencies because of physical properties.

The BMP effectiveness inputs to the Phase 5 model are calculated with the source information of the land use data after integrating BMPs that involve land use changes; the BMP implementation levels from Bay Program jurisdictions after compilation and computations for formatting and QA; and the BMP reduction efficiency file. These three sources are used to compute, by land-segment and by land use, the model input inputs according to the following equation:

$$\text{Fraction Reduction} = \frac{\text{acres treated by BMP}}{\text{total segment acres}} \times \text{BMP efficiency}$$

Built into the program are assignments for each BMP as to whether the practice is considered additive or multiplicative. BMPs that cannot be applied to the same land use are mutually exclusive and are considered additive in nutrient reduction capabilities. An example of additive BMPs would be stream-bank protection with fencing and without fencing where the pasture land has either type of protection, but never both.

The other type of BMP, which applies to most controls, is considered to be multiplicative and several BMPs are applied on the same land use. These practices are considered to behave as consecutive BMPs since one BMP reduces the nutrients available for subsequent BMPs to reduce. Multiplicative functions are applied to this class of BMP and an example of multiplicative BMPs would be cropland where cover crops, a conservation plan and riparian forest buffers down-gradient from cropland where are applied.

The product of the BMP relational database is, again, a spreadsheet file of pass-through factors for each land use and for TN, TP, and sediment by model land-segment. The Phase 5 Model "passes through" the fraction of the nutrient and sediment load resulting from the combined impact of BMPs. Pollutant reductions due to BMP land use changes are accounted for through the simulation of a lower-yielding land use. For details on how many of the BMP effectiveness estimates were assigned see: www.mawaterquality.org/bmp_reports.htm.

8.3.3 Application reduction BMPs

This kind of BMP is generally applied to animal units to accommodate BMPs like *phytase* where the BMP results in smaller amounts of nutrients. Application reduction BMPs are simple to quantify because the amount of phosphorus in excrement is easily measured before and after phytase feed additive. The application reductions need to be evaluated often to represent the current level of technology.

8.3.4 Load reduction BMPs

Load reduction BMPs are those that result in an amount of nutrient or sediment reduced per unit length or area. BMPs like Dirt and Gravel Road erosion and sediment controls receive an amount of sediment and phosphorus reduced per foot of implementation. Pounds of reduction per foot is a common unit of load reduction for this type of BMP.

8.3.5 System change BMPs

System change BMPs are utilized for septics that are converted to sewer. This is anaologous to a land use change where loads change based on the simulated loading of the land use, but septics and sewer are simulated on the same land use. The method of waste management is modeled within the urban land uses. See Section 6.9 for septic modeling.

8.4 Agricultural BMPs

8.4.1 Animal Waste Management Systems

Definition:	Practices designed for proper handling, storage, and utilization of wastes generated from confined animal operations.
Land use:	AFO (livestock, poultry)
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 80%, TP: 80%
Reference:	Appendix H, BMP Basics

8.4.2 Barnyard Runoff Control

Definition:	This practices includes the installation of practices to control runoff from barnyard areas. This includes practices such as roof runoff control, diversion of clean water from entering the barnyard and control of runoff from barnyard areas. Use the first percent efficiency if controls are installed on an operation with manure storage; and the second percent if the controls are installed on a loafing lot without a manure storage. The sediment efficiency has not been incorporated into the current watershed model but will be included in the updated model that is under development at this time.
Land use:	AFO
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP:20%, TSS:40%
Reference:	Tributary Strategies document

8.4.3 Loafing Lot Management

Definition:	The stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures. This does not include poultry pad installation.
Land use:	AFO
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP:20%, TSS:40%
Reference:	NRCS Practice 561:Heavy Use Area Protection NRCS Guide

8.4.4 Tree Planting

Definition:	Tree planting includes any tree planting, except those used to establish riparian forest buffers, targeting lands that are highly erodible or identified as critical resource areas.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, trp
Efficiency credited:	Landuse change to for
Effectiveness estimate:	N/A
Reference:	Appendix H

8.4.5 Non-Urban Stream Restoration

Definition:	A collection of site specific engineering techniques used to stabilize an eroding streambank and channel. These are areas not associated with animal entry.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, trp, urs
Efficiency credited:	Load reduction
Effectiveness estimate:	0.02 Lbs N/ ft; 0.003 lbs P/ft; 2 lbs Sed/ft
Reference:	MAWP

8.4.6 Mortality Composters (Poultry)

Definition:	A physical structure and process for disposing of dead poultry. Composed material is combined with poultry litter and land applied using nutrient management plan recommendations.
Land use:	AFO
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 40%, TP: 10%
Reference:	MAWP

8.4.7 Dairy Precision Feeding and Forage Management

Definition:	Dairy Precision Feeding: reduces the quantity of phosphorous and nitrogen fed to livestock by formulating diets within 110% of Nutritional Research Council recommended level in order to minimize the excretion of nutrients without negatively affecting milk production.
Animal type:	Dairy heifers
Efficiency Credited:	Application reduction
Effectiveness estimate:	Reported by states
Reference:	MAWP

8.4.8 Nutrient Management

Definition:	Nutrient management plan (NMP) implementation (crop) is a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. A NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates. Plans should be revised every 2 to 3 years.
Land use:	Hwm, hom, lwm, hyw, alf, pas
Efficiency credited:	Landuse change to nhi, nho, nlo, nhy, nal, npa, respectively
Effectiveness estimate:	N/A
Reference:	BMP Basics

8.4.9 Forest Buffers

Definition:	Agricultural riparian forest buffers are linear wooded areas along rivers, stream and shorelines. Forest buffers help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35 feet minimum width required.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, trp
Efficiency credited:	Landuse change to for and upland Efficiency
Effectiveness estimate:	Varies geographically TN: 19-65%(4x acres); TP: 30-45%(2x acres); TSS: 40-60%(2x acres)
Reference:	Forest buffer white paper

8.4.10 Grass Buffers

Definition:	Agricultural riparian grass buffers are linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment and other pollutant from runoff. The recommended buffer width for riparian forests buffers (agriculture) is 100 feet, with a 35 feet minimum width required.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, trp
Efficiency credited:	Landuse change to hyo and upland Efficiency
Effectiveness estimate:	Varies geographically TN: 13-46%(4x acres); TP: 30-45%(2x acres); TSS: 40-60%(2x acres)
Reference:	MAWP

8.4.11 Wetland Restoration

Definition:	Agricultural wetland restoration activities re-establish the natural hydraulic condition in a field that existed prior to the installation of subsurface or surface drainage. Projects may include restoration, creation and enhancement acreage. Restored wetlands may be any wetland classification including forested, scrub-shrub or emergent marsh.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, trp
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies geographically TN: 7-25%; TP: 12-50%; TSS: 15%
Reference:	MAWP

8.4.12 Conservation Tillage

Definition:	Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components, (a) a minimum 30% residue coverage at the time of planting and (b) a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface.
Land use:	Hwm, nhi
Efficiency credited:	Landuse Change to lwm and nlo, respectively
Effectiveness estimate:	N/A
Reference:	MAWP

8.4.13 Carbon Sequestration and Alternative Crops

Definition:	Carbon Sequestration refers to the conversion of cropland to hay land (warm season grasses). The hay land is managed as a permanent hay land providing a mechanism for sequestering carbon within the soil. (Note: this practice has not be incorporating into the watershed model nor has specifications been developed for its use as an approved BMP)
Land use:	Hwm, nhi, hom, nho, lwm, nlo
Efficiency credited:	Landuse change to hyo

Effectiveness estimate:	N/A
Reference:	BMP Basics

8.4.14 Conservation Plans

Definition:	Farm conservation plans are a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and to prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases the plan must meet technical standards.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, urs
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies by landuse TN: 3-8%; TP: 5-15%; TSS: 8-25%
Reference:	MAWP

8.4.15 Land Retirement

Definition:	Agricultural land retirement takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees. Agricultural agencies have a program to assist farmers in land retirement procedures.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo, pas, npa, (trp to hyo)
Efficiency credited:	Landuse change to hyo or pas according to practice
Effectiveness estimate:	N/A
Reference:	BMP Basics

8.4.16 Poultry and Swine Phytase

Definition:	Phytase can be injected into poultry feeds by the integrator or other feed suppliers. Manure phosphorous reductions occur because less phosphorous needs to be blended into feed rations, resulting in a phosphorous source reduction. See Section 4.1.3.
Animal type:	Broilers, pullets, layers, turkeys, sows, hogs for breeding, hogs for slaughter
Efficiency credited:	Application reduction
Effectiveness estimate:	Default: Broilers 16%; Layers 21%; Pullets 21%; Turkeys 16%; Sows and hogs 0%
Reference:	BMP Basics

8.4.17 Water Control Structures

Definition:	Installing and managing boarded gate systems in agricultural land that contains surface drainage ditches.
Land use:	Hwm, nhi, hom, nho, lwm, nlo, hyw, nhy, alf, nal, hyo
Efficiency credited:	Efficiency
Effectiveness estimate	TN: 33%
Reference:	WCS Reccs

8.4.18 Manure Transport

Definition:	Manure is transported by truck from the county of origin to another or out of the watershed. Manure transported to another county in the watershed results in increased manure mass in the receiving county.
Animal type:	Angora goats, beef heifers, broilers, dairy heifers, milk goats, hogs and pigs for breeding, hogs for slaughter, horses, layers, other cattle, pullets, sheep and lambs, turkeys,
Efficiency credited:	Application reduction
Effectiveness estimate:	N/A
Reference:	BMP Basics

8.4.19 Cover Crops

Definition:	Cereal cover crops reduce erosion and the leaching of nutrients to groundwater by maintaining a vegetative cover on cropland and holding nutrients within the root zone. This practice involves the planting and growing of cereal crops (non-harvested) with minimal disturbance of the surface soil. The crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. These crops capture or "trap" nitrogen in their tissues as they grow. By timing the cover crop burn or plow-down in spring, the trapped nitrogen can be released and used by the following crop. Different species are accepted as well as, different times of planting (early, late and standard), and fertilizer application restrictions. Manure application on cover crops is not modeled and acres of cover crops that receive manure are not eligible. There is a sliding scale of efficiencies based on crop type and time of planting.
Land use:	Hwm, hom, lwm, nhi, nho, nlo,
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies greatly, see Table 8-1: Types of conservation practices/BMPs.

Reference:	MAWP

8.4.20 Continuous No-Till

Definition:	The Continuous No-Till (CNT) BMP is a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. CNT involves no-till methods on all crops in a multi-crop, multi-year rotation. When an acre is reported under CNT, it will not be eligible for additional reductions from the implementation of other practices such as cover crops or nutrient management planning. Multi-crop, multi-year rotations on cropland are eligible. Crop residue should remain on the field. Planting of a cover crop might be needed to maintain residue levels. Producers must have and follow a current nutrient management plan. The system must be maintained for a minimum of five years. All crops must be planted using no-till methods.
Land use:	LWM
Efficiency credited:	Efficiency
Effectiveness estimate:	Varied by geography; TN: 10-15%; TP: 20-40%; TSS: 70%
Reference:	CNT Report

8.4.21 Ammonia Emissions Reduction

Description:	Litter amendments like alum suppress the formation of ammonia from ammonium in litter. Biofilters attached to animal enclosure ventilation systems detoxify ammonia.
Animal type:	Angora goats, beef heifers, broilers, dairy heifers, milk goats, hogs and pigs for breeding, hogs for slaughter, horses, layers, other cattle, pullets, sheep and lambs, turkeys,
Efficiency Credited:	Application reduction
Effectiveness Estimate:	Alum TN 50%; Biofilters TN 60%
Reference:	MAWP

8.4.22 Commodity Cover Crops and Small Grains

Definition:	Commodity cover crops differ from cereal cover crops in that they may be harvested for grain, hay or silage and they may receive nutrient applications, but only after March 1 of the spring following their establishment. The intent of the practice is to modify normal small grain production practices by eliminating fall and winter

	fertilization so that crops function similarly to cover crops by scavenging available soil nitrogen for part of their production cycle.
Land use:	Hwm, hom, lwm, nhi, nho, nlo,
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies, see Section Table 8-1: Types of conservation practices/BMPs.
Reference:	Appendix H

8.4.23 Decision Agriculture

Definition:	A management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment.
Land use:	Hom, hwm, hyw, lwm, alf
Efficiency credited:	Efficiency and landuse change to nutrient management equivalent
Effectiveness estimate:	TN: 4% is applied after landuse change
Reference:	NRCS practice Precision Ag

8.4.24 Enhanced Nutrient Management

Definition:	Based on research, the nutrient management rates of nitrogen application are set approximately 35% higher than what a crop needs to ensure nitrogen availability under optimal growing conditions. In a yield reserve program using enhanced nutrient management, the farmer would reduce the nitrogen application rate by 15%. An incentive or crop insurance is used to cover the risk of yield loss. This BMP effectiveness estimate is based on a reduction in nitrogen loss resulting from nutrient application to cropland 15% lower than the nutrient management recommendation. The effectiveness estimate is based on conservativeness and data from a program run by American Farmland Trust.
Land use:	Hom, hwm, hyw, lwm, alf
Efficiency credited:	Efficiency and landuse change to nutrient management equivalent
Effectiveness estimate:	TN: 7% is applied after landuse change
Reference:	MAWP

8.4.25 Horse Pasture Management

Definition:	Stabilizing overused small pasture containment areas (animal concentration area) adjacent to animal shelters or farmstead.
Land use:	Pas, npa
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: N/A TP: 20% TSS:40%
Reference:	MAWP

8.4.26 Alternative Watering Facilities

Definition:	Alternative watering facilities typically involves the use of permanent or portable livestock water troughs placed away from the stream corridor. The source of water supplied to the facilities can be from any source including pipelines, spring developments, water wells, and ponds. In-stream watering facilities such as stream crossings or access points are not considered in this definition. The modeled benefits of alternative watering facilities can be applied to pasture acres in association with or without improved pasture management systems such as prescribed grazing or PIRG. They can also be applied in conjunction with or without stream access control.
Land use:	Pas, npa
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 5%, TP: 8%, TSS: 10%
Reference:	Pasture science panel Reccs 3/18/10

8.4.27 Stream Access Control with Fencing

Definition:	Stream access control with fencing involves excluding a strip of land with fencing along the stream corridor to provide protection from livestock. The fenced areas may be planted with trees or grass, or left to natural plant succession, and can be of various widths. To provide the modeled benefits of a functional riparian buffer, the width must be a minimum of 35 feet from top-of-bank to fence line. If an entity is installing a riparian buffer practice in conjunction with stream protection fencing, and can track and report these installations, additional upland benefits of those riparian buffers can be applied in the model. The implementation of stream fencing provides stream access control for livestock but does not necessarily exclude animals from entering the stream by incorporating limited and stabilized in-stream crossing or watering facilities. The

	modeled benefits of stream access control can be applied to degraded stream corridors in association with or without alternative watering facilities. They can also be applied in conjunction with or without pasture management systems such as prescribed grazing or PIRG.
Land use:	trp
Efficiency credited:	Landuse change to hyo and upland Efficiency
Effectiveness estimate:	Varies geographically TN: 13-46%(4x acres); TP: 30-45%(2x acres); TSS: 40-60%(2x acres)
Reference:	Pasture science panel Reccs 3/18/10

8.4.28 Precision Intensive Rotational Grazing

Definition:	This practice utilizes more intensive forms pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas of the upland pastures. PIRG can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). The modeled benefits of the PIRG practice can be applied to pasture acres in association with or without alternative watering facilities. They can also be applied in conjunction with or without stream access control. This practice requires intensive management of livestock rotation, also known as Managed Intensive Grazing systems (MIG), that have very short rotation schedules. Pastures are defined as having a vegetative cover of 60% or greater.
Land use:	Pas, npa
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies by geography TN: 9-11%, TP: 24%, TSS: 30%
Reference:	Pasture science panel Reccs 3/18/10

8.4.29 Prescribed Grazing

Definition:	This practice utilizes a range of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas. PG can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). The modeled benefits of prescribed grazing practices can be applied to pasture acres in association with or without alternative watering facilities. They can also be applied in conjunction with or without stream access control. Pastures under the PG systems are defined as having a vegetative cover of 60% or

	greater.
Land use:	Npa, pas
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies by geography TN: 9-11%, TP: 24%, TSS: 30%
Reference:	Pasture science panel Reccs 3/18/10

8.5 Resource BMPS

8.5.1 Forest Harvesting Practices

Definition:	Forest harvesting practices are a suite of BMPs that minimize the environmental impacts of road building, log removal, site preparation and forest management. These practices help reduce suspended sediments and associated nutrients that can result from forest operations.
Land Use:	hvf, for
Efficiency Credited	Efficiency
Effectiveness Estimate	50% TN; 60% TP; 60% TSS
Reference	MAWP

8.5.2 Dirt and Gravel Road Stormwater Management Control

Definition:	Minimize stormwater runoff concentration and velocity, protect areas of concentrated flow from erosion, and prevent degradation of water quality or habit in local streams. There are three types with varying reductions: Driving Surface aggregate(DSA), no DSA and DSA with outlets
Land use:	For, pul, puh
Efficiency credited:	Load reduction
Effectiveness estimate:	DSA: 2.96 lbs Sed/ft; No DSA: 1.76 lbs Sed/ft;DSA w/ outlets: 3.6 lbs Sed/ft
Reference:	Eroison and Sediment Control CBC Final Report

8.5.3 Forest Conservation

Definition:	Urban forest conservation applies only to Maryland at this time. This BMP in Maryland is the implementation of the Maryland Forest Conservation Act that requires developers to maintain at least 20% of a development site in trees (forest condition). This is actually a

	preventative type of BMP which alters the rate of urban conversion. The acreage is calculated from the annual urban increase (population based). The 20% is specific to the Maryland Act and could be different for each jurisdiction or various locations within a jurisdiction.
Land use:	Pul, puh
Efficiency credited:	Landuse change to for
Effectiveness estimate:	N/A
Reference:	Appendix H

8.6 Urban BMPs

8.6.1 Dry Detention and Extended Detention Basins

Definition:	Dry extended detention (ED) basins are depressions created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry ED basins are designed to dry out between storm events, in contrast with wet ponds, which contain standing water permanently. As such, they are similar in construction and function to dry detention basins, except that the duration of detention of stormwater is designed to be longer, theoretically improving treatment effectiveness.
Land use:	Css, imh, iml, puh, pul
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP: 20%, TSS: 60%
Reference:	MAWP

8.6.2 Dry Detention Ponds/Hydrodynamic Structures

Definition:	*Dry Detention Ponds* are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. *Hydrodynamic Structures* are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff.

Land use:	Css, imh, iml, puh, pul
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 5%, TP: 10%, TSS: 10%
Reference:	MAWP

8.6.3 Erosion and Sediment Control

Definition:	Erosion and sediment control practices protect water resources from sediment pollution and increases in runoff associated with land development activities. By retaining soil on-site, sediment and attached nutrients are prevented from leaving disturbed areas and polluting streams.
Land use:	Bar, pul,
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 25%, TP: 40%, TSS: 40%
Reference:	MAWP

8.6.4 Urban Filtering Practices

Definition:	Practices that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media. There are various sand filter designs, such as above ground, below ground, perimeter, etc. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds due to the increased cation exchange capacity achieved by increasing the organic matter. These systems require yearly inspection and maintenance to receive pollutant reduction credit.
Land use:	Css, ext, imh, iml, puh, pul
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 40%, TP: 60%, TSS: 80%
Reference:	MAWP

8.6.5 Urban Infiltration Practices with sand/vegetation

Definition:	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration. Design specifications require infiltration basins and trenches to be build in good soil, they are not constructed on poor

	soils, such as C and D soil types. Engineers are required to test the soil before approved to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff.
Land use:	Css, ext, imh, iml, puh, pul
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 85%, TP: 85%, TSS: 90%
Reference:	MAWP

8.6.6 Wetlands and Wet Ponds

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Definition:	A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Until recently, these practices were designed specifically to meet water quantity, not water quality objectives. There is little or no vegetation living within the pooled area nor are outfalls directed through vegetated areas prior to open water release. Nitrogen reduction is minimal.
Land use:	Css, ext, imh, iml, puh, pul
Efficiency credited:	Effectiveness
Effectiveness estimate:	TN: 20%, TP: 45%, TSS: 60%
Reference:	MAWP

8.6.7 Urban Infiltration Practices without sand/vegetation

Definition:	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration.
Land use:	Css, ext, imh, iml, puh, pul
Efficiency credited:	Effectiveness
Effectiveness estimate:	TN: 80%, TP: 85%, TSS: 90%
Reference:	MAWP

8.6.8 Septic Connections

Definition:	This is when septic systems get converted to public sewer. This reduces

	the number of systems because the waste is sent into the sewer and treated at a wastewater treatment plant.
Land use:	sep
Efficiency credited:	Systems change
Effectiveness estimate:	N/A
Reference:	Appendix H; Jeff Sweeney

8.6.9 Urban Nutrient Management

Definition:	Urban nutrient management involves the reduction of fertilizer to grass lawns and other urban areas. The implementation of urban nutrient management is based on public education and awareness, targeting suburban residences and businesses, with emphasis on reducing excessive fertilizer use.
Land use:	Pul, puh
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 17%; TP: 22%
Reference:	Appendix H; CBP Nutrient and Sediment Tributary Strategy Workgroup Subcommittee

8.6.10 Septic Pumping

Definition:	Septic systems achieve nutrient reductions through several types of management practices, including frequent maintenance and pumping. On average, septic tanks need to be pumped once every three to five years to maintain effectiveness. The pumping of septic tanks is one of several measures that can be implemented to protect soil absorption systems from failure. When septic tanks are pumped and sewage removed, the septic system's capacity to remove settable and floatable solids from wastewater is increased.
Land use:	sep
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 55%
Reference:	Appendix H, BMP Basics

8.6.11 Septic Denitrification

Definition:	Septic denitrification represents the replacement of traditional septic systems with more advanced systems that have additional nitrogen removal capabilities. Traditional septic systems usually consist of a large tank designed to hold the wastewater allowing grits and solids time for settling and decomposition. Wastewater then flows to the second

	component, the drainfield. An enhanced septic system like that shown can provide further treatment of nitrogen through processes that encourage denitrification of the wastewater.
Land use:	sep
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 50%
Reference:	Appendix H, BMP Basics

8.6.12 Tree Planting

Definition:	Urban tree planting is planting trees on urban pervious areas at a rate that would produce a forest-like condition over time. The intent of the planting is to eventually convert the urban area to forest. If the trees are planted as part of the urban landscape, with no intention to covert the area to forest, then this would not count as urban tree planting
Land use:	Pul, puh
Efficiency credited:	Landuse change to for
Effectiveness estimate:	N/A
Reference:	Appendix H, BMP Basics

8.6.13 Urban Growth Reduction

Definition:	Change from urban to non-urban landuse in forecasted conditions.
Land use:	Imh, iml, puh, pul
Efficiency credited:	Landuse change to non-urban landuses
Effectiveness estimate:	N/A
Reference:	Old NPS table; Jeff Sweeney

8.6.14 Urban Stream Restoration

Definition:	Stream restoration in urban areas is used to restore the urban stream ecosystem by restoring the natural hydrology and landscape of a stream, help improve habitat and water quality conditions in degraded streams.
Land use:	Imh, iml, puh, pul
Efficiency credited:	Load reduction
Effectiveness estimate:	0.02 Lbs N/ ft; 0.003 lbs P/ft; 2 lbs Sed/ft
Reference:	WCS Reccs

8.6.15 Abandoned Mine Reclamation

Definition:	Abandoned mine reclamation stabilizes the soil on lands mined for coal or affected by mining, such as wastebanks, coal processing, or other coal

	mining processes.
Land use:	ext
Efficiency credited:	Landuse change to for
Effectiveness estimate:	N/A
Reference:	BMP Basics

8.6.16 Urban Forest Buffers

Definition:	An area of trees at least 35 feet wide on one side of a stream, usually accompanied by trees, shrubs and other vegetation, that is adjacent to a body of water. The riparian area is managed to maintain the integrity of stream channels and shorelines, to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals.
Land use:	Pul, puh
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 25%, TP: 50%. TSS: 50%
Reference:	MAWP - def

8.6.17 Street Sweeping

Definition:	Street sweeping and storm drain cleanout practices rank among the oldest practices used by communities for a variety of purposes to provide a clean and healthy environment, and more recently to comply with their National Pollutant Discharge Elimination System stormwater permits. The ability for these practices to achieve pollutant reductions is uncertain given current research findings. Only a few street sweeping studies provide sufficient data to statistically determine the impact of street sweeping and storm drain cleanouts on water quality and to quantify their improvements. The ability to quantify pollutant loading reductions from street sweeping is challenging given the range and variability of factors that impact its performance, such as the street sweeping technology, frequency and conditions of operation in addition to catchment characteristics. Fewer studies are available to evaluate the pollutant reduction capabilities due to storm drain inlet or catch basin cleanouts.
Land use:	Imh, iml
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 3%, TP: 3%, TSS: 9%
Reference:	Street sweeping

8.6.18 Bioretention with underdrain

Definition:	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which

	the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants.
Land use:	Imh, iml, pul, puh, css
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies by implementation TN: 25-80%, TP: 45-85%, TSS: 55-90%
Reference:	MAWP

8.6.19 Bioswale

Definition:	With a bioswale the load is reduced because unlike other open channel designs there is now treatment through the soil. A bioswale is designed to function as a bioretention area.
Land use:	Imh, iml, pul, puh, css
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 70%, TP: 75%, TSS: 80%
Reference:	MAWP

8.6.20 Impervious Surface Reduction

Definition:	Reducing impervious surfaces to promote infiltration and percolation of runoff storm water.
Land use:	Imh, iml
Efficiency credited:	Landuse change to pul or puh, respectively.
Effectiveness estimate:	N/A
Reference:	MAWP

8.6.21 Permeable Pavement with sand/vegetation

Definition:	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. When sand and vegetation are present, high reduction efficiencies can be achieved.
Land use:	Imh, iml, pul, puh, css
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20-80%, TP: 20-80%, TSS: 55-85%
Reference:	MAWP

8.6.22 Permeable Pavement without sand/vegetation

Definition:	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain.
Land use:	Imh, iml, pul, puh, css
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 10-75%, TP: 20-80%, TSS: 55-85%
Reference:	MAWP

8.6.23 Vegetated Open Channels

Definition:	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed, includes bioswales. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils.
Land use:	Imh, iml, pul, puh, css
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 10-45%, TP: 10-45%, TSS: 50-70%
Reference:	MAWP

For Dirt and Gravel Road Erosion and Sediment Control, please see Section 8.5.2 Error! Reference source not found.
For Forest Conservation, please see Section 8.5.3

8.7 Interim Agricultural BMPs

8.7.1 Cropland Irrigation Management

Cropland under irrigation management is used to decrease climatic variability and maximize crop yields. The potential nutrient reduction benefit stems not from the increased average yield (20-25%) of irrigated versus non-irrigated cropland, but from the greater consistency of crop yields over time matched to nutrient applications. This increased consistency in crop yields provides a subsequent increased consistency in plant nutrient uptakes over time matched to applications, resulting in a decrease in potential environmental nutrient losses.

The current placeholder effectiveness value for this practice has been proposed at 4% TN, 0%TP and 0%TSS, utilizing the range in average yields from the 2002 and 2007 NASS data for irrigated and non-irrigated grain corn as a reference. The proposed practice is applied on a per acre basis, and can be implemented and reported for cropland on both lo-till and hi-till land uses that receive or do not receive manure.

8.7.2 Cropland Drainage Phosphorus-sorbing Materials (PSMs)

The University of Maryland and the USDA Agricultural Research Service (ARS) have demonstrated through an existing research project at the University of Maryland-Eastern Shore the application of "Phosphorus-sorbing" materials to absorb available dissolved phosphorus in cropland drainage systems for removal and reuse as an agricultural fertilizer. These in-channel engineered systems can capture significant amounts of dissolved phosphorus in agricultural drainage water by passing them through phosphorus-sorbing materials, such as gypsum, drinking water treatment residuals, or acid mine drainage residuals.

The current placeholder effectiveness value for this practice has been proposed at 0% TN, 40%TP and 0%TSS, utilizing a conservative estimate in phosphorus removal measured by the UMD/ARS research project as a reference. The proposed practice is applied on a per acre basis, and can be implemented and reported for cropland on both lo-till and hi-till land uses that receive or do not receive manure. Based upon the documentation, the proposed practice is currently limited to Coastal Plain soils with shallow groundwater levels requiring drainage ditches for agricultural production.

8.7.3 Liquid Manure Injection

The subsurface application of liquid manure from cattle and swine has been demonstrated in research studies to significantly reduce nutrient losses for both surface runoff and ammonia emissions. Recent studies by Pennsylvania State University (PSU) and USDA-ARS indicate that the effectiveness of the practice is dependent on the technology used for injection, and that some systems are not consistent with the USDA-NRCS management requirements for high residue management systems; e.g. Continuous No-Till. This proposed practice is indicative of low disturbance soil injection systems and is not appropriate for tillage incorporation or other post surface application incorporation methods.

The current placeholder effectiveness value for this practice has been proposed at 25% TN, 0%TP and 0%TSS, utilizing a conservative estimate in combined nutrient and sediment loss reductions by current university and ARS research as a reference. The proposed practice is applied on a per acre basis, and can be implemented and reported for cropland on both lo-till and hi-till land uses that receive manure, pasture and hay with manure.

8.7.4 Poultry Manure Injection

The subsurface injection of poultry manure has been demonstrated in university and USDA-ARS research studies to significantly reduce nutrient losses for both surface runoff and ammonia emissions. Recent studies by universities and USDA-ARS indicate that dry manure injection is feasible and effective by utilizing current research technology. These systems are also consistent with the USDA-

NRCS management requirements for high residue management systems; e.g. Continuous No-Till. This proposed practice is indicative of low disturbance soil injection systems and is not appropriate for tillage incorporation or other post surface application incorporation methods.

The current placeholder effectiveness value for this practice has been proposed at 25% TN, 0%TP and 0%TSS, utilizing a conservative estimate in combined nutrient and sediment loss reductions by current university and ARS research as a reference. The proposed practice is applied on a per acre basis, and can be implemented and reported for cropland on both lo-till and hi-till land uses that receive manure, pasture and hay with manure.

8.7.5 Mortality Incineration

The definition of the approved BMP entitled Mortality Composting does not include the alternative process of incineration practiced by some livestock operations. The proposed interim practice of Mortality Incineration is defined as a physical structure and process for disposing of dead livestock and poultry through incineration versus composting. The resulting ash material is land applied using nutrient management plan recommendations. The current placeholder effectiveness value for this practice has been proposed at 40% TN, 10%TP and 0%TSS, utilizing the existing Mortality Composting effectiveness estimate as a reference. The proposed practice is applied on a livestock type and operation basis, and can be implemented and reported for the AFO land use.

8.7.6 Vegetative Environmental Buffers (VEB)

A vegetative environmental buffer, or VEB, is the strategic dense planting of combinations of trees and shrubs around poultry houses to address environmental, production, and public relations issues. Research conducted by the University of Delaware have indicated that mature tree plantings can offer filtration benefits for poultry operations by entrapping dust, odor, feathers, and noise emitted by air exhaust from ventilation systems. Documentation on the effectiveness of VEB's in reducing nitrogen losses to the environment through ammonia emission reductions is currently non-conclusive. The current placeholder effectiveness value for this practice will be described as a land use change for the area directly planted to trees and shrubs. The proposed practice is applied on a per acre basis, and results in a conversion to forest land from cropland, on both lo-till and hi-till land uses that receive manure or do not receive manure, pasture or hay land with or without nutrients.

It's important to note that a recent scientific analysis report from the University of Maryland/Mid-Atlantic Water Program, funded by EPA, indicated that the practice has not undergone a science-based evaluation by the Chesapeake Bay Program Partnership to be included on the official list of agricultural BMPs in the models. Available scientific data on the potential nutrient reductions associated with VEB's is unfortunately very limited at this time. A recent study conducted by Dr. Bud Malone with the University of Delaware on VEB's demonstrated the ability of vegetative buffers to remove (filter) dust and associated ammonia emissions vented from poultry houses. Unfortunately, the study was not able to determine the fate of those emissions once they were filtered by the vegetation. The Chesapeake Bay Program Partnership's Agriculture Workgroup, which is responsible for recommending new agricultural BMPs to the Partnership for inclusion in the models, has identified this issue as one needing further research and study to determine the potential nutrient reduction effectiveness values.

8.7.7 Manure Processing Technology

As part of the innovative advanced technology element for the Watershed Implementation Plan (WIP), PA DEP is working with the Pennsylvania Department of Agriculture and a number of companies looking to install various technologies such as methane digesters and electrical co-generation on dairy, poultry and hog operations. Many of these technologies can produce electricity and marketable soil amendments; reduce methane emissions; and generate renewable energy, nutrient reduction and carbon credits that can then be sold. Some forms of technology, such as digesters, alone will not substantially change the nutrient content of manure. Pennsylvania is looking more closely at technologies that include a process element that helps ensure overall nutrient reductions. Examples of nutrient processing technology include: denitrification; solids separation; flocculation, combustion, etc.

DEP has formally approved several technologies for nutrient credit generation. As part of this approval, a process for quantifying credits is approved as well as a plan to verify the reductions. Each technology or process has been different, but the approvals contain several common requirements critical to quantification such as 1) Throughput of manure is monitored for the quantity being processed; 2) Sampling for nutrient content is performed at various key stages of the process, such as the inlet and the outlets to the process; and 3) The number of credits are reduced if the overall process indicates a need to account for either the process' product potentially introducing reduced nutrients back to the watershed (e.g. stack emissions), or if nutrients are applied to replace manure that was previously land applied.

To allow for recognition in the Watershed Implementation Plan of the nutrient reductions associated with manure processing technology efforts, EPA has worked with PA to develop a placeholder Best Management Practice (BMP) and a process for crediting the resulting nutrient reductions.

8.7.8 Passive Hay Production

The Chesapeake Bay Program Bay Watershed Model currently has the land use category "hay with nutrients" set at 80 lbs N/acre and 40 lbs P/acre for NY. After discussion with USC Agricultural committee, an interim BMP was developed that reflected additional savings farmers have been implementing to reduce N and P on their hay fields. Farmers have reported using fewer nutrients on rented hay fields due to the uncertainty of long-term use, cost of fuel and fertilizer, and ability to use naturally fertilized hayfields.

Farmers developed a BMP where they eliminated nutrient spreading on some of their hayland. The USC analyzed 15,402 acres of hay land from nutrient management plans. The analysis prorated each field's nutrient load according to size. Information was garnered throughout the watershed to reflect regional differences.

For N and P, the BMP is to spread the CBP nutrient load per acre 80 pounds of N on 61% the each farm's hayland (model and analysis virtually same at 80 and 79 pounds). For P the CBP rate of 40 pounds is spread on 48 % of all hayland (to account for 40 pounds P in model versus 32 pounds applied). On the remainder of the hayland (39% and 52 %, respectively,) no N or P of any sort is spread, leaving this hay to be fertilized solely by atmospheric deposition. These figures are supported by the references below.

8.7.9 Container Nursery and Greenhouse Runoff and Leachate Collection and Reuse

This practice involves the collection of runoff water from container nursery operations where runoff of irrigation water and leachate from plant containers grown on plastic or in greenhouses is routed to lined return ditches or piped to lined holding ponds. Ponds would be designed to retaining all excess irrigation water runoff or leachate and capturing the first one-half to one-inch of stormwater runoff. Water would be recirculated for irrigation in nursery and greenhouse operations or irrigated at the proper times of year on other vegetation capable of trapping nutrients at agronomic rates, such as cool season grasses. Proposed BMP efficiency would be the same as for an animal waste storage system: 75% N reduction, 75% P reduction. This BMP is requested by Virginia DCR.

8.8 Interim Stormwater BMP

8.8.1 Volume Reduction and/or Retention Standard

This BMP credits efforts to increase the retention of stormwater on site or reduce the volume of stormwater entering the edge of stream. DC used a 1.2 inch retention standard and NY's WIP included a 50% volume reduction of stormwater on some urban acres. This is modeled as a conversion of impervious urban acres to urban acres that achieve a known volume reduction. Each jurisdiction has its own average and this was used to achieve a specified benefit. A similar practice with an implicit model reduction is known as impervious surface reduction.

8.9 BMP Annual Time Series

The structure of Scenario Builder and Phase 5 Model allows annual changes in land use and in BMPs as explained in more detail in Phase 5 Model documentation Section 12. The complete time series of information on BMPs as applied in the Phase 5 land-segments from 1985 to 2005 can be found at the Chesapeake Community Modeling Program's (CCMP) Phase 5 data library located on the web at: http://ches.communitymodeling.org/models/CBPhase5/datalibrary.php.

8.10 BMP effectiveness adjustment

High rainfall events can also influence BMP function and efficiency particularly for events above a BMP's designed maximum storm (Maule et al., 2005 and Glozier et al., 2006). Conservation practices are designed to function up to a specific storm event, for example a 10-year storm. Many continue to perform in more intense storm events. However, there is a level of storm intensity that impedes performance, and in extreme circumstances, may prevent nutrient or sediment reduction altogether. Research that estimates performance boundaries related to weather events is sparse. In addition, conservation practices may perform above literature values during low intensity storm events.

The weather adjustment links an expected loss in BMP efficiency due to storm intensity (Table 6.1.2). Only post-processed conservation practices receive this form of adjustment as land use change and explicit simulation of BMP would already have the effect of large events directly simulated. This adjustment is additive.

Table 8-2: Table of expected loss in efficiency due to storm intensity.

Storm Recurrence Frequency	*Efficiency Level*
0-15 year storm	conservation practice efficiency
5-50 year storm	70% of conservation practice efficiency
51+ year storm	30% of conservation practice efficiency

9 REVIEWS

9.1 Internal and external review

The objective in conducting reviews was to: 1) mirror in Scenario Builder the actual practices used by the agricultural community, and 2) correctly reflect the urban loadings. An extensive team of people both internal and external to the Chesapeake Bay Program were consulted throughout the development process. Working through a team brought diverse perspectives and made Scenario Builder more accurately reflect on-the-ground practices.

Internal reviews were conducted with he Chesapeake Bay Program modeling and nutrient staff (Jing Wu, Gary Shenk, Lewis Linker, Jeffrey Sweeney, and Mark Dubin), and the software development team leader (Jessica Rigelman). Each set of requirements were presented, discussed, and edited as recommended.

External guidance was provided primarily by:

1. Karl Berger-MWCOG
2. William Keeling-VA-DCR
3. Larry Fender-VA-DCR
4. Kenn Pattison-PA-DEP
5. Norm Goulet-Northern Virginia Regional Commission
6. David Kindig-VA-DCR
7. William Angstadt-MD and VA Fertilizer Sales Consultant
8. Bobby Long-VA-DCR Nutrient Management Planner
9. Edward Joyner-VA-DCR-Nutrient Management Planner
10. Robert Shoemaker-VA-DCR Nutrient Managed Planner
11. Doug Goodlander-PA State Conservation Commission
12. Don Fiesta-PA-DEP
13. Bill Rohr-Delaware Department of Agriculture

A series of conference calls were conducted from August through October, 2009. Each call addressed a different set of calculation procedures. In addition, Patricia Steinhilber-Program Coordinator, Agricultural Nutrient Management Program of the University of Maryland and David Hansen-University of Delaware Extension Program Leader for Agriculture and Natural Resources, were consulted throughout.

A joint meeting of the Agricultural and Nutrient and Sediment Reduction Workgroup and the Watershed Technical Workgroup was held 12/11/2008. Minutes from this meeting may be found on the Chesapeake Bay Program's website (http://www.chesapeakebay.net/committee_agworkgroup_meetings.aspx?menuitem=16733). The primary purpose was to approve source data and also review all the calculation processes for determining uptake and application rates. The group provided valuable input on volatilization changes to beef and hogs where beef TN would be 42.5% and hogs and pigs for breeding and growing TN would be 30%. However, since volatilization occurs after the nutrients are split into the various species of N and P, then these values were unable to be incorporated. Members of these workgroups also advised on the amount of time horses and heifers spend in pasture. As a result, changes were made to these variables. In addition, the workgroup members identified a more comprehensive source of data for animal manure speciation (ASAE, 2003). The workgroup members were in consensus that the ratio of NH_3 to NO_3 for inorganic fertilizer was incorrect, but no method was agreed upon for how to make a more representative split.

9.2 Validation

Data generated by the tool were compared to those that were produced from the Watershed Model Phase 4.3.

Test cases were developed and conducted parallel to the actual Watershed Model-HSPF calibration. The data from the Agricultural Census was spot checked by John Clune of USGS. His analysis was presented at the aforementioned joint workgroup meeting on 12/11/2008.

Further quality control and quality assurance procedures were implemented by TreCom for checking results. These checks compared output to expected results with extensive input deck test cases. This quality checking resulted in a high degree of confidence in Scenario Builder's functionality.

10 APPENDICES

10.1 *Manure and Fertilizer Application Process* (*J. Rigelman 01/30/09*)

1. Calculate Best Potential and Max Application Mass and Rate
    a. The best potential and max should be the total mass needed by the crop inclusive of starter mass
    b. This is calculated for crops on land uses keeping double cropped crops separate by major nutrient by month

2. Calculate Starter Application Mass and Rate
    a. This is calculated for crop on land uses keeping double cropped crops separate by nutrient by month
    b. Starter is calculated from best potential application mass, not max.
    c. There is no starter max.

3. Calculate Direct Deposit Manure
    a. This is calculated on a monthly basis and nutrients and sources are kept separate

4. Calculate Manure and Biosolid Storage Loss
    a. This is calculated on a monthly basis and sources and nutrients are kept separate

5. Calculate Stored Manure and Biosolids
    a. This is calculated on an annual basis and sources and nutrients are kept separate

6. Apply Starter
    a. Apply fertilizer equal to the N and P starter mass.
    b. Take amount applied and subtract from best potential and max application masses.
    c. Take amount applied and add to applied source total.

7. Apply Storage Loss Manure to AFO
    a. Take all manure lost in storage and put on AFO land use.
    b. Keep months, animals, nutrients separate.
    c. AFO has no crops. Therefore, AFO has no N and P application mass.

8. Apply Direct Deposit Manure
    a. This manure is applied to pasture land uses – PAS, NPA, TRP
    b. TRP has an acres effective area of 9* the actual acres.
    c. This data is available monthly and will need to be applied monthly and animals and nutrients are should be kept separate
    d. DO NOT take the mass of the plant available N and plant available P pooped in pasture and subtract from best potential and max application mass. Take the total mass of N and total mass of P pooped in pasture and add to applied source total.
    e. If more nutrients pooped in pasture than is needed by the crops, apply it all anyway, since direct deposit is not applied against the application rate.
9. Apply Biosolids
    a. Biosolids are available by yearly total.

b. Whether a crop is eligible to receive biosolids is determined by
    i. If the crop is on a land use that can receive manure
    ii. If the crop-land use can receive biosolids.
    iii. If the crop-land use has a remaining best potential or max application mass
c. The annual amount of biosolids should be proportioned across the months based on remaining best potential and max application mass for crop-land use combinations that are eligible to receive biosolids.
d. Once the biosolids are proportioned monthly, the monthly allocation is applied in crop set order.
e. If the amount of biosolids available is between best potential and max then best potential must be met for all crops in all months before proportioning out the remainder to the remaining max application mass.
f. Take the mass of the plant available N and plant available P in biosolids that were applied and subtract from best potential and max application mass. Take the total mass of N and total mass of P in biosolids that were applied and add to applied source total.
g. Crop, land use, source, nutrient, month should all be kept separate.
h. If there are biosolids remaining after meeting max, an error is logged with the amount of biosolids that could not be applied.

10. Apply Stored Manure
    a. Stored manure is available by yearly total.
    b. Whether a crop is eligible to receive manure is determined by
        i. If the crop is on a land use that can receive manure
        ii. If the crop-land use has a remaining best potential or max application mass
        iii. It is assumed that if a crop is on a land use that can receive manure that it can receive all animal sources of manure.
    c. The annual amount of stored manure should be proportioned across the months based on remaining best potential and max application mass for crop-land use combinations that are eligible to receive manure.
    d. Once the stored manure is proportioned monthly, the monthly allocation is applied in crop set order.
    e. If the amount of manure available is between best potential and max then best potential must be met for all crops in all months before proportioning out the remainder to the remaining max application mass.
    f. If there is manure remaining after spreading the max for all crop-land use combinations, the remainder is eligible for transport.
    g. Take the mass of the plant available N and plant available P in manure that was applied and subtract from best potential and max application mass. Take the total mass of N and total mass of P in manure that was applied and add to applied source total.
    h. Crop, land use, source, nutrient, month should all be kept separate.

11. Manure Transport
    a. Manure can only be transported to another county if it shares a border.
    b. Manure transport cannot cross state lines.
    c. Only counties that have excess manure after meeting max application mass for all crop-land use combinations that can receive manure are eligible for transport.
    d. The order in which counties transport within a state is based on the greatest amount of excess manure.
    e. Manure is transported to adjacent counties proportionally based on the remaining best potential application mass. If an adjacent county does not have enough manure to meet best potential than you will transport to it.

f. Manure is transported to all adjacent counties proportionally based on adjacent counties remaining application mass.
g. Never transport manure to an adjacent county to meet a crops max application mass.
h. Transported manure is spread the same way stored manure is spread.
i. If a county cannot transport all of its excess manure to adjacent counties, the remainder goes to disposal load.

12. Disposal Load
    a. Apply disposal load manure to crops on the land use non nutrient management pasture (PAS) first.
    b. Apply disposal load manure to crops on the land use trampled riparian pasture (TRP) second if not eliminated on PAS.
    c. Apply disposal load manure to crops on the land use hay with nutrients (HYW) third if not eliminated on TRP.
    d. Apply disposal load manure to crops on the land use non nutrient management row w/manure (HWM, LWM) forth if not eliminated on HYW.
    e. If there is still excess after applying to HWM and LWM crops, an error is logged with the amount of disposal load that could not be applied.
    f. Sum max application mass for all crops on the land use(s) you are applying to annually.
    g. Multiply the annual sum for all crop times 10 to get the annual disposal load application mass for all crop on the land use(s).
    h. Proportion the annual mass across the months equally. 1/12 for each month.
    i. Apply the monthly allocation the crops in the land use(s) proportionally based on the proportion of acres in the crop to the total acres of the crops in the land use(s).
    j. If you have more manure than disposal load need in that land use(s) move to next land use(s)
    k. Take the total mass of N and total mass of P in the disposal manure that was applied and add to applied source total. There is no reason to subtract from application mass.

13. Apply Fertilizer
    a. Apply fertilizer to crops to meet remaining N and P best potential application mass
    b. Do not apply fertilizer to meet max
    c. Do not apply fertilizer to crops that do not take fertilizer as a source.
    d. Some crops only take fertilizer as a source and do not take biosolids or manure.
    e. Fertilizer is mixed to the exact remaining N and P application mass. If there is no remaining N application mass after manure spreading but P application mass remains then the fertilizer applied would only contain P.

10.2 Unexposed Soil Surface (O. Devereux, 4/17/2009)

Uses data:

County
Plant and harvest dates
Tillage practice: low till or high till as associated with land use
Soil surface cover by month
Acres of crops
Double cropped

1. Calculate crop residue cover
    a. For each crop and double cropped crop and tillage practice in each county, multiply the monthly soil surface cover fraction (given in a source data table) by the acres of cropland to get acres/month.
    b. Sum the crop residue cover by land use for each month to get land use acres/month.
2. Divide the monthly acres of unexposed soil surface cover from #1 by the total acres of land in that land use. This gives the percent cover by land use.
3. This calculation is bound where:
    a. monthly value is < 0.95
    b. monthly value is >zero

10.3 Double cropping Requirements

The actual procedure is below.

1. Acquire "Harvested Cropland Area" for a county from Ag census
2. Summarize the acreage of double crop ineligible crops from the following types in Ag census
    - Alfalfa Hay Harvested Area
    - Cut Christmas Trees Production Area
    - Cut Christmas Trees Production Area
    - Floriculture crops – bedding/garden plants, cut flowers and cut florist greens, foliage plants, and potted flowering plants, total Area
    - Floriculture crops – bedding/garden plants, cut flowers and cut florist greens, foliage plants, and potted flowering plants, total Protected Area
    - Land in Orchards Area
    - Other managed hay Harvested Area
    - short-rotation woody crops Harvest Area
    - short-rotation woody crops Production Area
    - Small grain hay Harvested Area
    - Wild hay Harvested Area
3. Subtract ineligible crops from cropland area
4. If the resultant area is negative, then reset or redefine the cropland area equal to the summarized crop acreage calculated in step 2 above.
5. Summarize the acreage of "double cropped eligible" crop types
    a. Identify the *double cropped eligible* crop types by county.
    b. Summarize (add) the acreage of these crop types.
6. Subtract the area determined from step **Error! Reference source not found.**(Initial Land Area) from the area determined in step **Error! Reference**

source not found. (Initial Double-Cropped Area). This difference yields the acres double cropped.

a. When this number is a positive number (more crop acreage than land area), it represents the *area double cropped*. Proceed to Step 4.

b. When this number is negative (less double-crop acreage than land area), re-set the *Initial land area* to be equal to the *Initial double-crop area*. In this case, no land is double cropped.

7. Determine the first (spring/summer) *crop-specific acres double-cropped*. Summarize acreage of crop types listed as a *first crop* in Table 7-2, and determine crop-specific proportions of the total. Multiply the crop-specific proportions with the *area double cropped* (from step 0) to get the *crop-specific acres double cropped*.

   For example, if corn is 50%, sunflower seed-oil is 2%, and sorghum is 48% of land acreage as reported in the agricultural census, then the number of acres double-cropped will be covered by 50% corn, 2% sunflower seed-oil, and 48% sorghum (This example assumes there are enough acres of the first crop to accommodate all acres of the second double-croppable crop).

8. The second set of crops that should be paired with the early season crops (corn varieties, sunflower seed-oil, and sorghum) are soybeans, barley, and total winter grains based on crop-specific proportional acreage. The full list is presented in table Table 7-2 (as first and second crop columns).

   For example, if corn is 50%, sunflower seed-oil is 2%, and sorghum is 48% of land acreage as reported in the agricultural census, then the number of acres double-cropped will be covered by 50% corn, 2% sunflower seed-oil, and 48% sorghum (This example assumes there are enough acres of the first crop to accommodate all acres of the second double-croppable crop).

9. These acres will be stored by the county and year marked as double-cropped crop. It is a separate category of crop type because it will eventually have its own plant and harvest dates as well as fertilizer application amount and time.

10. Acres of the soybeans, total winter grains group, or barley that exceed the corn varieties, sunflower oil-seed, or sorghum variety acres available for double-cropping remain as a single crop. These excess acres are not considered to be double-cropped. The initial land area should be increased to reflect that these crops have not been double-cropped.

    Example: Initial land area = 100

    First Crop area = 300
    Second Crop area = 50

If the second crop is double-croppable, the initial land area should be increased from 100 to 250. If the second crop is not double-croppable the land area would be increased from 100 to 350.

Note:

Double cropping cover is addressed by classifying a double-cropped crop as its own crop type with different plant and harvest dates than the same crop that is not double-cropped. Since the first crop planted is not considered as the double-crop, then those dates are not shortened to reflect what may be an earlier harvest. Therefore, there may be some overestimate of cover from leaf area coverage and an underestimate of residue cover during the harvest time of the first crop and the planting time of the double crop.

This process selects the residue cover or the canopy cover fraction, whichever is higher. An underestimation may result in early plant growth period for low till crops because residue may still be on the ground and leaf cover may not overlap. This is not an issue for high till crops where most of the residue is plowed under at planting.

NRCS Practice Standard 345 for Residue Management Mulch Till states, "The annual Soil Tillage Intensity Rating (STIR) value for all soil-disturbing activities shall be no more than 70 for high residue crops (e.g., grain corn) and no more than 10 for low residue crops (e.g., grain soybeans). These STIR values will result in approximately 30% or more surface residue for the entire crop rotation." By using the RUSLE2 tillage management practices, the data necessarily meets the conservation tillage STIR values.

Where inconsistencies or error introduced in the estimation of withheld ("D") data led to inconsistencies between crop areas and land areas, then the land areas were adjusted to be commiserate with the crop areas.

All failed cropland is included in the Watershed Model land use hay-fertilized. The agricultural census does not report which crops failed. Therefore, whatever failed is not double cropped.

Corn and sorghum are equally likely to be double cropped in this model.

Maryland currently has a cover crop program that allows a partial payment for crops planted but not harvested when no nutrients are applied in the fall and a smaller payment if the farmer applies spring nutrients and harvests the crop for sale (R. Wieland, personal communication, 2008). This may provide some overlap in NASS data for small grains and cover crops reported as a best management practice

Vegetables that are grown in plasticulture are not treated differently in this model. Plasticulture–managed vegetables are grown so that approximately one third of a field is covered(Ed Joiner, Nutrient Management Planner, VA). This increases infiltration since the irrigation system is under the plastic and decreases erosion. It also decreases volatilization. If plasticulture is about 7,000 acres in Virginia, and there are 195,000 acres in high-till row crop without manure (HOM), then these acres comprise 3.6% of the total and the plastic-covered portion of the field is 1.1% of that land use. Therefore, this is assumed to be insignificant portion for the outcome of loads.

Sunflower can be for seed oil or for wildlife. Where sunflower is grown for wildlife stands then it is not double cropped but left fallow. NASS reports sunflowers in two categories: Sunflower seed, non-oil varieties and Sunflower seed, oil varieties. Only sunflower seed, oil variety is available to be double cropped. Years prior to 2002 do not have sunflower seed split into the two categories, so double cropping is not calculated for sunflowers prior to the categorization split. Rather, sunflower-all are categorized as sunflower non-oil varieties for the years prior to 2002.

Barley can be grown for grain or silage, yet the agricultural census does not differentiate. Barley for silage is lumped into the category haylage, grass silage, or greenchop whereas corn and sorghum silage or greenchop are distinct. Where grown for silage it is harvested 1.5 months earlier and is double-cropped with either sorghum or corn. This is common in the dairy industry (Bobby Long, Nutrient Management Planner, VA). Since the source data do not allow barley for silage as a distinct category, barley effectively will only be double cropped as a grain with sorghum.

While potatoes grown in the southern portion of the Chesapeake Bay Watershed are harvested early enough that they may be double cropped with beans and wheat, they are not included as a crop that may be double cropped with anything other than vegetables (Ed Joiner, Nutrient Management Planner, VA). Vegetables are double cropped. This is handled by multiple plant and harvest dates within each crop type or the land use.

An additional step that is not yet implemented in Scenario Builder development is to verify that the timing of plant and harvest dates by growth region do not result in two crops growing at the same time. That is, if corn is planted in April and harvested in August, then soybeans can not be planted in July. In this case, apply the double cropping to a different available crop (among corn, sorghum, and sunflowers) where there is no overlap of crop plant and harvest time periods.

10.4 Legumes

The Agricultural Census categories that include legumes but are not exclusively legumes are not considered for legume fixation. We assume the area comprising legumes is insignificant.

Each year is considered independent of any other year. Therefore, nutrients can not "build up" in the soil in data produced by the Scenario Builder. It follows that N in the soil after one year may repress N fixation. This situation is not considered in the calculation of these data.

No N is fixed in the month of planting. We assume that the nodules take 2-4 weeks to establish. For subsequent months of growth, the total amount of NH_3 is parsed evenly. That means that the same amount of N is fixed in month 2 as in the final month before the plant is killed or dies. A perennial, like alfalfa, will fix the same amount every month between emergence (plant date for annuals) and first hard frost (harvest date for perennials).

We assume that fixation occurs on all leguminous plants. This assumes that legumes are inoculated or sufficient rhizobia are present. It also assumes that carbon is at optimum levels.

Nitrogen fixation amounts are not adjusted for temperature or rainfall in the Chesapeake Bay Program's Watershed Model. The exception is alfalfa. As of October 14, 2008, nitrogen fixation for alfalfa will likely be calculated by the Watershed Model so that rainfall and temperature data can parameterize fixation amounts.

The Chesapeake Bay Program's Watershed Model accounts for processes that occur after N fixation, such as where crops are killed and left on the soil or incorporated into the soil, thereby returning N to the soil.

Many researchers have indicated that fertilizer application in the form of NO_3 does not decrease N fixation by legumes (Johnson et al., 1975; Blumenthal et al., 1996). These data refute the dogma that NO_3 substitutes for fixed N where NO_3 is increased. Literature searches did not produce data that quantifies the reciprocally of the NO_3 sorption and N2 fixation. Without identifying values of N fixation and the interaction with NO_3 for each leguminous plant, we are unable to consider these data in our model.

References

Bourion, 2007; Xu-Ri and Prentice, 2008; Johnson et al., 1975; Blumenthal et.al., 1996.

10.5 Land Use (O. Devereux, P. Claggett, J. Sweeney, G. Shenk, 1/27/2009)

Note on precision:

Land use acreage is an intermediate calculation between source data sets and loads, rather than a reported value, so values should not be rounded. On the output step, there should be at least 7 significant digits as the values are read in as single precision FORTRAN variables

Note on Time Scale:

Each run of the scenario builder land use calculation creates a data set that represents a single point in time or a year if the outputs are monthly. The direct inputs to the scenario builder land use calculation are files that represent a single set of assumptions. These files are

1. urban (5 uses), extractive, water, total acres by LRseg
2. crop types and animals by county from the Ag census
3. BMPs by LRseg

These files are identified by a scenario identifier that may or may not pertain to any given year. The calibration is a particular set of cases of the scenario builder land use generator where the inputs and outputs represent each year from 1982-2005.

Spatial reference:

"County" means County or independent city, referenced by the 5-digit FIPS code
"Lseg" = Land segment, which are divisions of counties. Referenced by the 5-digit FIPS code, with a preceding "A", "B", or "C"
"Rseg" = River segment or watershed, independent of county or lseg, referenced by a 13-character name, with the form XYn_1234_5678 where:

X = major basin
Y = minor basin
n = logarithmic reference to stream size
1234 = unique numerical ID, semi-randomly assigned
5678 = downstream ID. The unique ID of the downstream segment
Rsegs can be referenced by their full 13-character name or just their unique ID

LRseg = spatial intersection of the Lsegs and Rsegs. Referenced by the concatenation of thier names

10.6 Integrating Ag census with other data sources and scaling from County to Land-River Segmentation

Procedure 1: Creating "CBP Ag LU by LRseg"

INPUTS

1. P5lc

Tabular summary of raster land cover acres with unique classes for undefined agriculture (AG), cropland (CROP), and pasture/hay (PH) by Lrseg

Note: this will be static for the calibration and most scenarios.

Nursery, row crops with and without manure are considered CROP. Hay with and without nutrients, alfalfa and pasture are considered PH.

2. Agricultural Land Uses by County

These data are in a source table derived from the Agricultural Census above. Where the steps below refer to a land use, perform the same procedure on all of the crops in that land use.

3. AG Land Cover Index = AG / (CROP + PH)

Distribute undefined agriculture land cover into cropland and pasturehay land cover classes at the LRseg scale.

1. For LRsegs with a non-zero Ag Land Cover Index that is also less than 1, inflate the PH and CROP acres by distributing the undefined agriculture (AG) class to PH and CROP based on the proportions of PH and CROP in each LRseg.

1a. Create a multiplier = (PH + CROP +AG)/(PH + CROP)

This must always be >= 1

1b. Multiply PH and CROP by this multiplier

2. For LRsegs with no undefined agriculture (AG) and for LRsegs where the Ag Land Cover Index >=1 (e.g., the amount of undefined agriculture equals or exceeds the combined amount of PH and CROP), distribute the undefined agriculture (AG) class to LRsegs based on the proportions of pasturehay land use (CountyPastureHay) and cropland land use (CountyCropland) to total amount of agricultural land uses reported in the 2002 County Agricultural Census:

2a. PH = PH + (AG * CountyPastureHay/TotalCountyAgriculture)

2a. CROP = CROP + (AG * CountyCropland/TotalCountyAgriculture)

3. You now have PH and CROP acres for all LRsegs and zero 'AG' acres for all LRsegs, The acres do not add up to the Ag census, however.

Distribute the ag land use classes based on the proportion of each ag land cover class within each LRseg

For all 'crop' classes:

Acres of crop land uses = acres of CROP in lrseg / acres of CROP in county

Do the same for PH

For a zero Ag Land Cover Index and crops available to go on that land, apply proportional to the lrseg acres / county acres.

AFOs are disaggregated to land river segments proportional to the area of all agricultural acres in each LRseg to the total agricultural acres in the county.

Procedure 2: Creating "CBP Land Use by LRseg"

INPUT
1. "CBP Ag LU by LRseg", from procedure 1
2. "CBP Urban LU by LRseg" – external table
3. Total Acres by LRseg – external table
4. water acres by LRseg – external table
5. extractive acres by LRseg – external table

The purpose of this procedure is to assemble the data set from different sources. Since these are based on different data sets, they do not add up to 100% of the area. Some guidelines have been developed in order of importance:
1. Total LRseg size and water must be preserved
2. Forest is found by subtraction

Procedure: follow for each Lrseg

Forest = total acres minus water, ext, urban, and ag.
If forest is non-negative STOP

Set AcresNeeded = -forest
Set forest to zero

Low intensity pervious urban = Low intensity pervious urban - AcresNeeded
If low intensity pervious urban is non-negative STOP

Set AcresNeeded = -(low Intensity pervious urban)
Set Low intensity pervious urban to zero

If ag > 0
    Set ag multiplier = 1 - (AcresNeeded)/(total ag)   (multiplier < 1)
    Multiply all ag categories by the ag multiplier
    If ag multiplier is positive STOP

    Set AcresNeeded = - (total ag)
    Set all ag to zero
End if ag > 0

If total urban > 0
    Set urban multiplier = 1 - (AcresNeeded) / (total urban)
    Multiply all urban categories by the urban multiplier
    If urban multiplier is positive STOP

    Set AcresNeeded = - (total urban)
    Set all urban to zero
End If total urban > 0

Set ext = LRseg total minus water
If ext positive STOP

Set ext = 0
Set water = LRseg total

End Procedure

10.7 Classifying Nutrient Applications in Terms of Land Use

Nutrients are eligible to be applied to land based on the land use in which they are classified. Table 10-1 indicates which broader categorization of agricultural land each land use falls into: row, hay, or pasture. These classifications are used to establish the eligibility of manure and/or fertilizer applications to crops within each of these land uses.

Table 10-1: Nutrient type classifications

Name	Short Name	Tillage	Row	Hay	Pasture	Nutrient Management	Manure	Fertilizer
animal feeding operations	afo	NA	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
alfalfa	alf	NA	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
hightill without manure	hom	High	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE
hightill with manure	hwm	High	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE
hay without nutrients	hyo	NA	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
hay with nutrients	hyw	NA	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
lowtill with manure	lwm	Low	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE
nutrient management alfalfa	nal	NA	FALSE	TRUE	FALSE	TRUE	TRUE	TRUE
nutrient management hitil with manure	nhi	High	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
nutrient management hitil without manure	nho	High	TRUE	FALSE	FALSE	TRUE	FALSE	TRUE
nutrient management hay	nhy	NA	FALSE	TRUE	FALSE	TRUE	TRUE	TRUE
nutrient management lotil	nlo	Low	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
nutrient management pasture	npa	NA	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
pasture	pas	NA	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
degraded riparian pasture	trp	NA	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE
nursery	urs	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
low intensity pervious urban	Pul	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
high intensity pervious urban	Puh	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE

10.8 Detached Sediment

1) The purpose of the Detached Sediment logic is to determine the increase in the monthly amount of erodible sediment by Phase 5 land use (post-bmp) for a Land Segment in a given year. Key factors needed are the growing area, Crop Name, Crop Acreage, Planting & Harvesting dates, a reference table containing crop-specific rates of sedimentation (months after planting).
    a. The amt. of erodible sediment must be determined for a crop. The erodible sediment rate is influenced by soil disturbance (determined from planting and harvest dates). Because more than one planting/harvest dates may be provided for a crop, the detached sediment calculations should incorporate all planting and harvesting dates; a second, third, or fourth planting would contribute to the amt. of erodible sediment.
2) For each combination of Crop and Till Class (Hi/Low) a monthly increase in the amount of erodible sediment will be calculated in tons/acre.
    a. The rate of increase in the monthly amt. erod. sed. and the months relative to planting/harvesting will be stored in the database (by growing region,

crop name, tillage type). Note that months may be zero or negative (negative indicating months prior to the plant/harvest date).

   b. The months relative to planting/harvesting should be added/joined to the actual plant and harvest dates to determine which month the rate is associated with. (Join by growing region, crop name, tillage type.)
   c. The rates should be summarized by cropname and month.

3) The erodible sediment for each crop should be weighted by the crop-specific acreage and summarized by Land Segment, P5 landuse & month.
   a. Each crop-specific monthly rate should be weighted by the crop acreage (multiply acreage and monthly rate).
   b. The crop-specific acreage should be summarized by P5 landuse categories.
   c. The monthly, weighted rates for all crops should be summarized by the P5 landuse (acreage total that has already accounted for doublecropping) and Land Segment and then divided by the total acreage.
   d. The output format should be a comma delimited file with the following name: "dets_{descriptor}.csv" where {descriptor} is the name of the Scenario Builder scenario. Column headings are specified in the use case file.

Non-Point Source Best Management Practices and Efficiencies currently used in Scenario Builder ***Values in parentheses are in progress of official approval***					
Agriculture BMPs		***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Nutrient Management Application		Application Reduction	N/A	N/A	N/A
Forest Buffers (varies by region; see Appendix 2)		Efficiency, Landuse Change	19-65%	30-45%	40-60%
Wetland Restoration (varies by region; see Appendix 2)		Efficiency	7-25%	12-50%	4-15%
Land Retirement		Landuse Change	N//A	N/A	N/A
Grass Buffers (varies by region; see Appendix 2)		Efficiency, Landuse Change	13-46%	30-45%	40-60%
Non-Urban Stream Restoration		Mass reduction/length	N/A	N/A	N/A
Tree Planting		Landuse Change	N/A	N/A	N/A
Carbon Sequestration/Alternative Crops		Landuse Change	N/A	N/A	N/A
Conservation Tillage		Landuse Change	N/A	N/A	N/A
Continuous No-Till (varies by region; see Appendix 2)		Efficiency	(10-15%)	(20-40%)	(70%)
Enhanced Nutrient Management		Efficiency	(7%)	(N/A)	(N/A)
Decision Agriculture		Efficiency	(4%)	(N/A)	(N/A)
Conservation Plans	High-till	Efficiency	8%	15%	25%
	Low-till	Efficiency	3%	5%	8%
	All hay	Efficiency	3%	5%	8%
	Pasture	Efficiency	5%	10%	14%
Cover Crops (see Appendix 1)		Efficiency	Varies	Varies	Varies
Commodity Cover Crops (see Appendix 2)		Efficiency	Varies	Varies	Varies
Stream Access Control with Fencing		Landuse Change	(N/A)	(N/A)	(N/A)
Alternative Watering Facility		Efficiency	(5%)	(8%)	(10%)
Prescribed Grazing/PIRG		Efficiency	(9%)	(24%)	(30%)
Horse Pasture Management		Efficiency	(N/A)	(20%)	(40%)
Animal Waste Management Livestock		Efficiency	75%	75%	N/A
Animal Waste Management Poultry		Efficiency	75%	75%	N/A

Barnyard Runoff Control	Efficiency	20%	20%	40%
Loafing Lot Management	Efficiency	20%	20%	40%
Mortality Composters	Efficiency	40%	10%	N/A
Water Control Structures	Efficiency	33%	N/A	N/A
Poultry Phytase	Application Reduction	N/A	N/A	N/A
Swine Phytase	Application Reduction	N/A	N/A	N/A
Dairy Precision Feeding and Forage Management	Application Reduction	N/A	N/A	N/A
Poultry Litter Transport	Application Reduction	N/A	N/A	N/A
Ammonia Emissions Reduction (interim)	Application Reduction	(N/A)	(N/A)	(N/A)
Poultry Litter Injection (interim)	Efficiency	25%	0%	0%
Liquid Manure Injection (interim)	Efficiency	25%	0%	0%
Phosphorus Sorbing Materials in Ditches (interim)	Efficiency	40%	0%	0%
Resource BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Harvesting Practices	Efficiency	50%	60%	60%
Dirt & Gravel Road Erosion & Sediment Control – Driving Surface Aggregate + Raising the Roadbed	Mass reduction/length	N/A	N/A	N/A
Dirt & Gravel Road Erosion & Sediment Control – with outlets	Mass reduction/length	N/A	N/A	N/A
Dirt & Gravel Road Erosion & Sediment Control – outlets only	Mass reduction/length	N/A	N/A	N/A
Urban BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Conservation	Landuse Change	N/A	N/A	N/A
Urban Growth Reduction	Landuse Change	N/A	N/A	N/A
Impervious Urban Surface Reduction	Landuse Change	N/A	N/A	N/A
Forest Buffers	Efficiency, Landuse Change	25%	50%	50%

Tree Planting		Landuse Change	N/A	N/A	N/A
Abandoned Mine Reclamation		Landuse Change	N/A	N/A	N/A
Wet Ponds and Wetlands		Efficiency	20%	45%	60%
Dry Detention Ponds and Hydrodynamic Structures		Efficiency	5%	10%	10%
Dry Extended Detention Ponds		Efficiency	20%	20%	60%
Infiltration Practices w/o Sand, Veg.		Efficiency	80%	85%	95%
Infiltration Practices w/ Sand, Veg.		Efficiency	85%	85%	95%
Filtering Practices		Efficiency	40%	60%	80%
Erosion and Sediment Control		Efficiency	25%	40%	40%
Nutrient Management		Efficiency	17%	22%	N/A
Street Sweeping		Load reduction/length	N/A	N/A	N/A
Urban Stream Restoration		Load reduction/length	N/A	N/A	N/A
Septic Connections		Systems Change	N/A	N/A	N/A
Septic Denitrification		Efficiency	50%	N/A	N/A
Septic Pumping		Efficiency	5%	N/A	N/A
Bioretention	C/D soils, underdrain	Efficiency	25%	45%	55%
	A/B soils, underdrain	Efficiency	70%	75%	80%
	A/B soils, no underdrain	Efficiency	80%	85%	90%
Vegetated Open Channels	C/D soils, no underdrain	Efficiency	10%	10%	50%
	A/B soils, no underdrain	Efficiency	45%	45%	70%
Bioswale		Efficiency	70%	75%	80%
Permeable Pavement w/o Sand, Veg.	C/D soils, underdrain	Efficiency	10%	20%	55%
	A/B soils, underdrain	Efficiency	45%	50%	70%
	A/B soils, no underdrain	Efficiency	75%	80%	85%
Permeable Pavement w/ Sand, Veg.	C/D soils, underdrain	Efficiency	20%	20%	55%
	A/B soils, underdrain	Efficiency	50%	50%	70%
	A/B soils, no underdrain	Efficiency	80%	80%	85%

Appendix 2 BMPs	Hydrogeomorphic Region(s)	*TN Reduction Efficiency*	*TP Reduction Efficiency*	*SED Reduction Efficiency*
Forest Buffers	Appalachian Plateau Siliciclastic Non-Tidal	54%	42%	56%
	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal	34%	30%	40%
	Coastal Plain Dissected Uplands Non-Tidal	65%	42%	56%
	Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Piedmont Crystalline Tidal	19%	45%	60%
	Coastal Plain Lowlands Non-Tidal	56%	39%	52%
	Piedmont Crystalline Non-Tidal	56%	42%	56%
	Coastal Plain Uplands Non-Tidal	31%	45%	60%
	Piedmont Carbonate Non-Tidal	46%	36%	48%
	Valley and Ridge Siliciclastic Non-Tidal	46%	39%	52%
Grass Buffers	Appalachian Plateau Siliciclastic Non-Tidal	38%	42%	56%
	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal	24%	30%	40%
	Coastal Plain Dissected Uplands Non-Tidal	46%	42%	56%
	Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Piedmont Crystalline Tidal	13%	45%	60%
	Coastal Plain Lowlands Non-Tidal	39%	39%	52%
	Piedmont Crystalline Non-Tidal	39%	42%	56%
	Coastal Plain Uplands Non-Tidal	21%	45%	60%
	Piedmont Carbonate Non-Tidal	32%	36%	48%
	Valley and Ridge Siliciclastic Non-Tidal	32%	39%	52%
Wetland Restoration (Ag & Urban)	Appalachian Plateau Siliciclastic Non-Tidal	7%	12%	4%
	Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal	25%	50%	15%

	Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Piedmont Carbonate Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal	14%	26%	8%
Continuous No-till	Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal	10%	20%	70%
	Appalachian Plateau Siliciclastic Non-Tidal; Blue Ridge Non-Tidal; Mesozoic Lowlands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Piedmont Carbonate Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal	15%	40%	70%
Cover Crop Early Drilled Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	45%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	34%	15%	20%
Cover Crop Early Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	38%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	29%	15%	20%
Cover Crop Early Aerial Soy Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	31%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	24%	15%	20%
Cover Crop Early Aerial Corn Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	18%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	14%	15%	20%
Cover Crop	Coastal Plain/Piedmont Crystalline/Karst Settings*	41%	7%	10%

Standard Drilled Rye (Low-till gets only TN efficiency)	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	31%	7%	10%
Cover Crop Standard Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	35%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	27%	7%	10%
Cover Crop Late Drilled Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	19%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	15%	N/A	N/A
Cover Crop Late Other Rye (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	16%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	N/A	N/A
Cover Crop Early Drilled Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	31%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	24%	15%	20%
Cover Crop Early Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	27%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	20%	15%	20%
Cover Crop Early Aerial Soy Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	22%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	17%	15%	20%

Cover Crop Early Aerial Corn Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	15%	20%
Cover Crop Standard Drilled Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	29%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	22%	7%	10%
Cover Crop Standard Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	24%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	18%	7%	10%
Cover Crop Late Drilled Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	N/A	N/A
Cover Crop Late Other Wheat (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	11%	N/A	N/A
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	9%	N/A	N/A
Cover Crop Early Drilled Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	38%	20%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	29%	20%	20%
Cover Crop Early Other	Coastal Plain/Piedmont Crystalline/Karst Settings*	32%	15%	20%

Barley (Low-till gets only TN efficiency)	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	25%	15%	20%
Cover Crop Early Aerial Soy Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	27%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	20%	15%	20%
Cover Crop Early Aerial Corn Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	15%	20%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	15%	20%
Cover Crop Standard Drilled Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	29%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	22%	7%	10%
Cover Crop Standard Other Barley (Low-till gets only TN efficiency)	Coastal Plain/Piedmont Crystalline/Karst Settings*	24%	7%	10%
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	19%	7%	10%
Commodity Cover Crop Early Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	17%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	15%	(N/A)	(N/A)
Commodity Cover Crop Early Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	7%	(N/A)	(N/A)

Commodity Cover Crop Early Aerial Soy Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	12%	(N/A)	(N/A)
Commodity Cover Crop Early Aerial Corn Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	7%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)
Commodity Cover Crop Standard Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	7%	(N/A)	(N/A)
Commodity Cover Crop Late Drill Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	7%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)
Commodity Cover Crop Late Other Wheat	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Early Drill Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	9%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	6%	(N/A)	(N/A)
Commodity Cover Crop Early Aerial Soy	Coastal Plain/Piedmont Crystalline/Karst Settings*	6%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	5%	(N/A)	(N/A)

Barley				
Commodity Cover Crop Early Aerial Corn Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	13%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Drill Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	12%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	10%	(N/A)	(N/A)
Commodity Cover Crop Standard Other Rye	Coastal Plain/Piedmont Crystalline/Karst Settings*	18%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	14%	(N/A)	(N/A)
Commodity Cover Crop Early Other Barley	Coastal Plain/Piedmont Crystalline/Karst Settings*	15%	(N/A)	(N/A)
	Mesozoic Lowlands/Valley and Ridge Siliciclastic**	11%	(N/A)	(N/A)

*Coastal Plain Dissected Uplands Non-Tidal; Coastal Plain Dissected Uplands Tidal; Coastal Plain Lowlands Tidal; Coastal Plain Uplands Tidal; Coastal Plain Lowlands Non-Tidal; Coastal Plain Uplands Non-Tidal; Valley and Ridge Carbonate Non-Tidal; Piedmont Carbonate Non-Tidal

** Appalachian Plateau Siliciclastic Non-Tidal; Mesozoic Lowlands Non-Tidal; Piedmont Crystalline Tidal; Piedmont Crystalline Non-Tidal; Valley and Ridge Siliciclastic Non-Tidal; Blue Ridge Non-Tidal

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